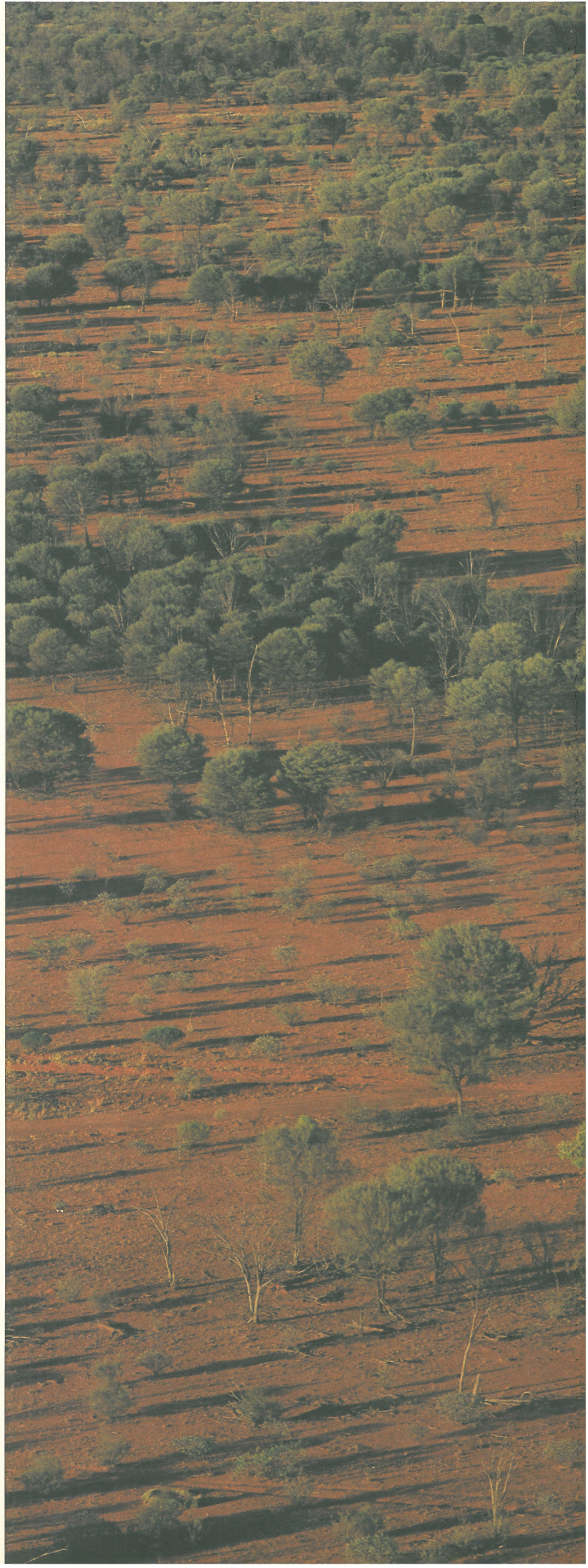
Atlas of Australian Resources

VEGETATION



Atlas of Australian Resources

Third Series

Volume 6

VEGETATION

AUSLIG
Australian Surveying and Land Information Group
Department of Administrative Services
'Service is our Business'
Canberra 1990

Preface

This atlas volume summarises current geographical knowledge about Australia's vegetation and complements the other environmental and resource topics in the Atlas of Australian Resources. It comes at the beginning of the Decade of Land Care, a time when there is a growing need for a complete picture of Australia's diverse and changing vegetation cover, to foster a fuller understanding and better management of our finite natural resources.

The view of Earth from space and the current concern about environmental change reinforce the importance of regional and even global perspectives on major resource use decisions. That realisation has come to this continent only two centuries after its colonisation by Europeans. But in that time the impact of present land use has significantly changed the original vegetation over a third of Australia.

The first section of the volume summarises the classification which was adopted to describe differences in plant cover and the technique used to map those differences over the entire continent. The main commentary gives a systematic description of the different vegetation types, both natural and modified, accompanied by numerous small maps that show the historical changes and also highlight some familiar floristic types. The volume concludes by considering vegetation change over the last two centuries, the major impacts on the original vegetation and some important environmental consequences.

The two major maps, Natural Vegetation and Present Vegetation, show the broad character of the vegetation, defined in terms of its growth form, foliage cover and predominant genus, for both the 1780s and the 1980s. They are based on satellite imagery and bring together a wide range of other information on vegetation. The mapping was carried out after extensive discussions on methods and source materials between the consultant, Dr John Carnahan (Botany Dept, Australian National University), and many people throughout Australia.

Natural Vegetation is a reconstruction of pre-European vegetation, making use of historical records and remnant vegetation in modified areas. Although the term 'natural' is applied to this vegetation, it was in fact influenced by thousands of years of Aboriginal land management. Present Vegetation is the first map to show the actual vegetative cover of the entire continent and it may serve as a benchmark for future studies of environmental change. These two maps also allow a quantitative assessment of the changes that have taken place over the last 200 years.

Preparation of the two 1:5 million scale maps proved to be a major undertaking and involved the work of many staff geographers, under the direction of John Carnahan and Frank Bullen. The commentary was written by John Carnahan and Ted Deveson. The design and cartographic supervision for this volume were by Ian King.

Volumes in this atlas

1. **Soils and Land Use**
2. **Population**
3. **Agriculture**
4. **Climate**
5. **Geology and Minerals**
6. **Vegetation**

Abbreviations

Standard abbreviations for Australian states and territories are used throughout this volume

NSW	New South Wales
NT	Northern Territory
Qld	Queensland
SA	South Australia
Tas.	Tasmania
Vic.	Victoria
WA	Western Australia

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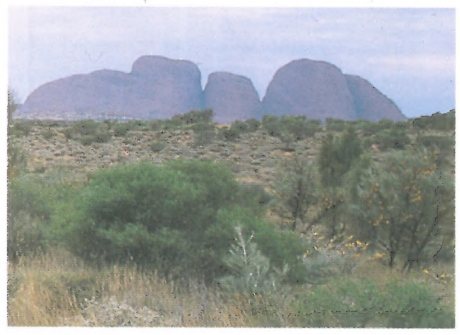


Australian vegetation

Introduction

The stunted trees and spinifex along Australia's western shores presented an uninviting picture of an arid continent to the first European visitors. The east coast, blanketed by moist forests, was seen far more favourably—as a land to be colonised. To Joseph Banks, the botanist with Captain Cook when he landed here in 1770, this vegetation appeared full of promise in its exotic diversity. But to many settlers of the 19th century it came to represent the harshness and fruitlessness of an inhospitable land. The image of an immense and monotonous scrub, seen as an obstacle to be removed from the landscape, became well established during the time of agricultural expansion.

Even today, for most people the enduring image of Australia's natural vegetation remains one of endless tracts of the familiar hard-leaved eucalypts and wattles. At the same time, the now largely urban population sees the bush as a friendly place to visit and its unique character forms a valued part of our distinct national identity. Yet in the space of a few generations the landscape in some agricultural regions has changed so rapidly that areas of natural vegetation have contracted to become remnant islands.

The maps in this volume show the present vegetative cover and a reconstruction of the pre-colonisation vegetation. Together, they show the distribution and magnitude of the broad changes that have occurred over the last 200 years. While the vegetation structure of more than half of the continent remains largely unaltered, the development of areas of agricultural potential has seen the removal of much of the natural vegetation.

In the years since the Second World War there has been as much land clearance as there had been in the preceding 150 years. In parts of the south-east and south-west natural vegetation survives as isolated trees or in narrow strips along roadways.

Time scales of change

This continent's vegetation has never been static. The climatic shifts of past geological ages led gradually to the evolution of much of the arid-adapted flora from moist Tertiary rainforests. The dramatic climatic changes of the most recent ice-ages changed critical environmental conditions over wide areas and caused large movements in the zonation of vegetation.

Australia's vegetation was also influenced by humans prior to European settlement. Significant changes in its structure and composition resulted from many thousands of years of Aboriginal land use. In particular, fire-tolerant species became more prominent and open wooded grasslands were maintained by Aboriginal burning practices.

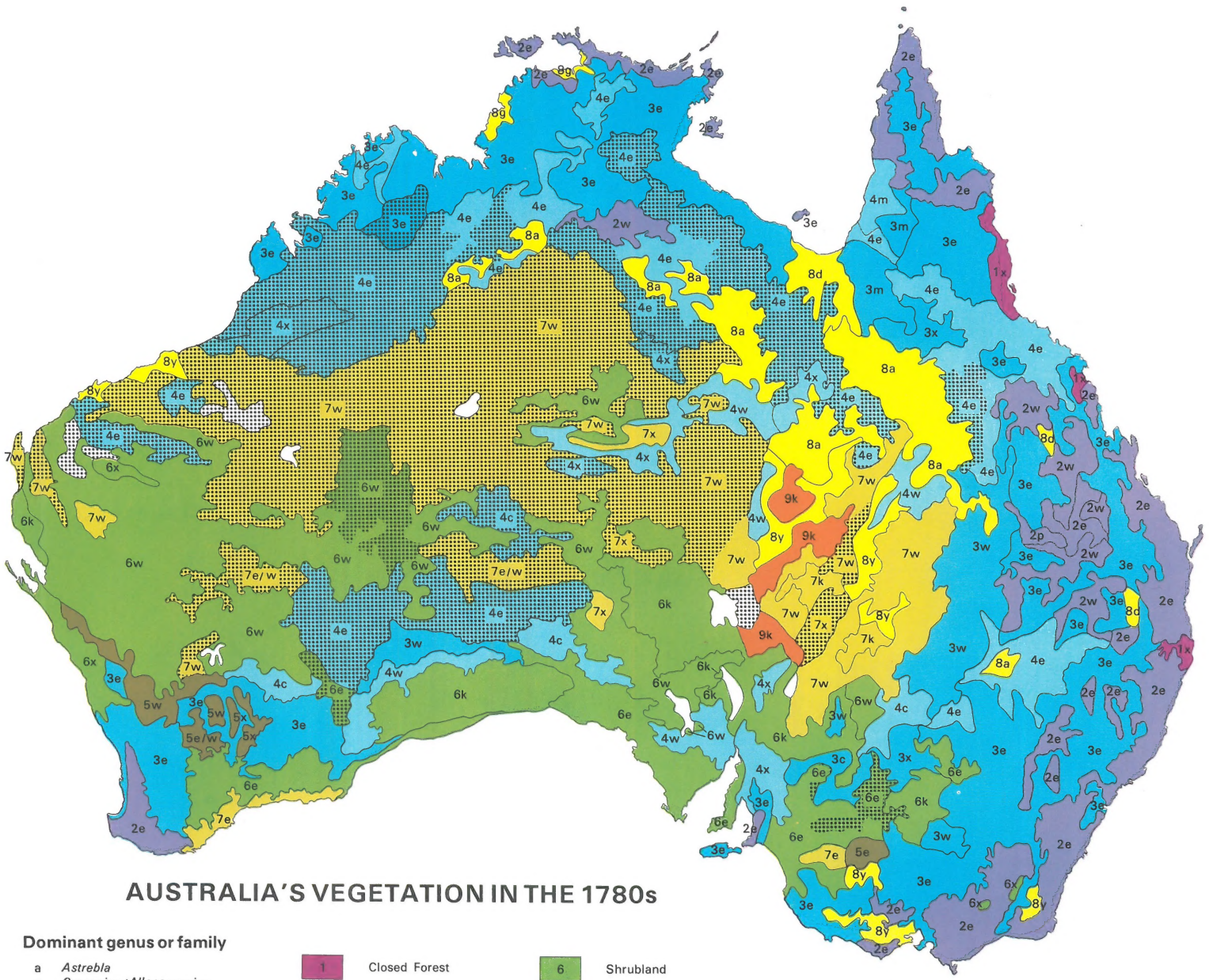
But even this relatively recent influence would have been only gradual when compared to the sudden impact of just two centuries of European land use, which brought extensive clearing and new plants and animals. Urban and rural development have vastly changed the former vegetation and supplanted it with new and generally well regulated vegetation types.

European settlement has been described by some ecologists as having been catastrophic for the flora and fauna of Australia. Many species and vegetation habitats have been lost but much has also been saved; large tracts of near-pristine bushland are now conserved in national parks and nature reserves. The larger part of the remaining forest land is now managed for multiple use—to allow both conservation and continued timber harvesting.

Environmental awareness has grown in recent times and, as attention turns to the last undeveloped regions in the country, the natural values of these areas are now given equal weight in planning. Issues of long-term environmental degradation aside, Australia has gained a primary production industry which has established it as a developed nation and which still helps maintain a high standard of living.

Patterns of change

The maps are a generalisation of complex vegetation patterns and often complex changes. At the



AUSTRALIA'S VEGETATION IN THE 1780s

Dominant genus or family

- a *Astrebla*
- c *Casuarina / Allocasuarina*
- d *Dichanthium*
- e *Eucalyptus*
- g Graminoids
- k Chenopodiaceae
- m *Melaleuca*
- n *Nothofagus*
- p *Callitris*
- w *Acacia*
- x Mixed or other
- y Other grasses

- 1 Closed Forest
- 2 Open Forest
- 3 Woodland
- 4 Open Woodland
- 5 Scrub and Heath
- 6 Shrubland
- 7 Open Shrubland
- 8 Grassland and sedgeland
- 9 Herbland
- Spinifex

Unvegetated salt lakes shown white

SCALE 1:20 000 000

SOURCE: Based on 1:5M 'Natural Vegetation' map.

continental scale the coding of wide areas of the present vegetation is the same as for the past, but on the ground there are very few places where there is no evidence of European impact on the vegetation, even if it is only the presence of alien weeds along bush tracks.

Throughout the grazing lands there has been a gradual shift in the composition of the shrub and ground layers of vegetation. Inedible species have increased at the expense of more sensitive ones and in many areas these changes were already taking place before botanical surveys were begun. The species involved in the shrub regrowth problem in parts of the inland have undergone a dramatic increase in recent decades. These species were in fact only minor components of the vegetation when selectors first moved onto the land.

While the general pattern of historical vegetation change has been one of reduction in biomass, it has not been entirely uniform. There are examples where the density of particular layers has increased in response to changed environmental factors or the introduction of new species.

In addition, the history of vegetation changes has often been more complex than a single directional shift from the natural to the present state. Many areas now covered by dense vegetation may have undergone several episodes of clearing and regeneration. The two hundred year timespan of European influence exceeds the reproductive age of tree species, so some areas of present forest may represent regrowth from previous clearing.

What is vegetation?

The term vegetation describes the entirety of the plant cover—individual plants collectively form distinct floristic associations and spatial patterns. It is these patterns which constitute the different vegetation types which we know as forest or heath or grassland.

Vegetation has been classified by such patterns into 'structural forms', distinctive arrangements of plant height and spacing that can occur over large areas. It is subdivided by the understorey type and by the taxonomic group of the dominant plants, usually to the level of genus or family.

The maps

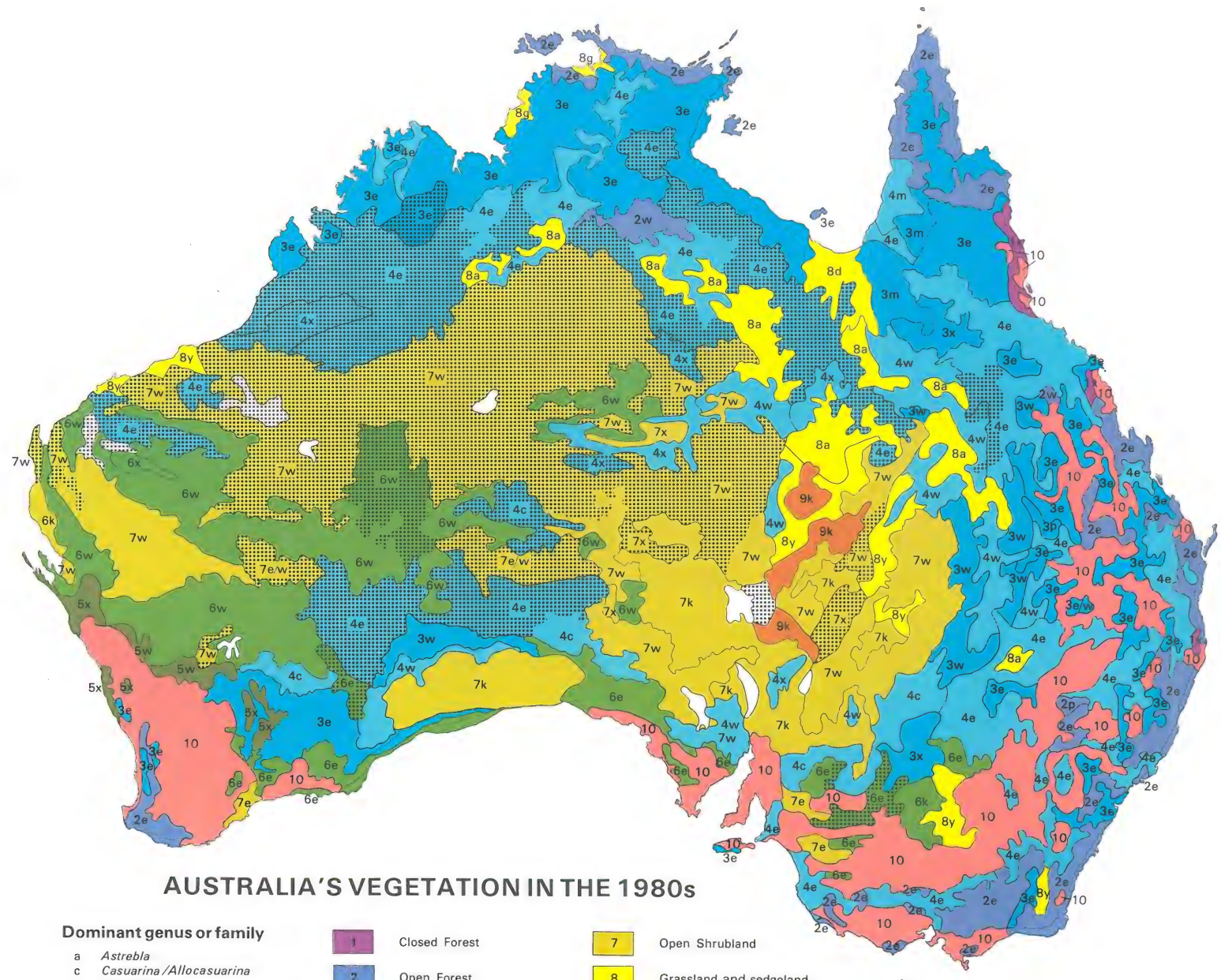
The primary mapping source for the present vegetation was Landsat satellite imagery. Landsat scanners are well suited to the detection of dense vegetation. The imagery is therefore an ideal tool for mapping land clearance and separating vegetation types. Information on structure and floristic composition was drawn from a wide range of secondary sources, mainly larger scale maps and reports on vegetation, along with some field verification.

The reconstruction of the former vegetation in areas where it has been substantially altered is based largely on remnant vegetation and historical sources. Where vegetation has been removed, boundaries are drawn from information on soils and other features. However, reconstruction of parts of the natural vegetation, particularly in south-eastern Australia, remains largely speculative because of inadequate historical information.

The major impact on the natural vegetation has been the change from forest and woodland to pasture and cropping. This stands out clearly on the summary maps below, which were generalised from the two major maps in the volume. The most dramatic changes are in the temperate south-east and south-west of the continent.

The largest areas of the new vegetation follow the familiar boundaries of the Australian wheatbelt, extending north into the former brigalow lands of eastern Qld. Lesser shifts in the foliage cover and floristic composition have occurred over a much wider area—roughly a third of the continent's vegetation has undergone structural changes resulting from European land use.

The extent of dryland cropping is nearing its climatic limits and vegetation resources for timber and pastoral production, though renewable, are finite in area and ultimately in yield. The most widespread vegetation types, covering much of the dry interior, are suitable only for sparse grazing. Despite its huge land area, Australia is no longer regarded as an unlimited frontier for agricultural development. We now have an overall picture of vegetation cover to support programs underway for the sustainable continued use of the country's environmental resources.



AUSTRALIA'S VEGETATION IN THE 1980s

Dominant genus or family

- a *Astrebla*
- c *Casuarina/Allocasuarina*
- d *Dichanthium*
- e *Eucalyptus*
- g Graminoids
- k Chenopodiaceae
- m *Melaleuca*
- n *Nothofagus*
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- 9 Herbland
- 10 Pasture and Cropping
- Spinifex

Unvegetated salt lakes shown white

SCALE 1:20 000 000

SOURCE: Based on 1:5M 'Present Vegetation' map.

Influences on vegetation

Despite the profound effect of humans, especially over the past 200 years, the physical environment remains the overriding influence on the distribution of Australia's vegetation types.

Environment

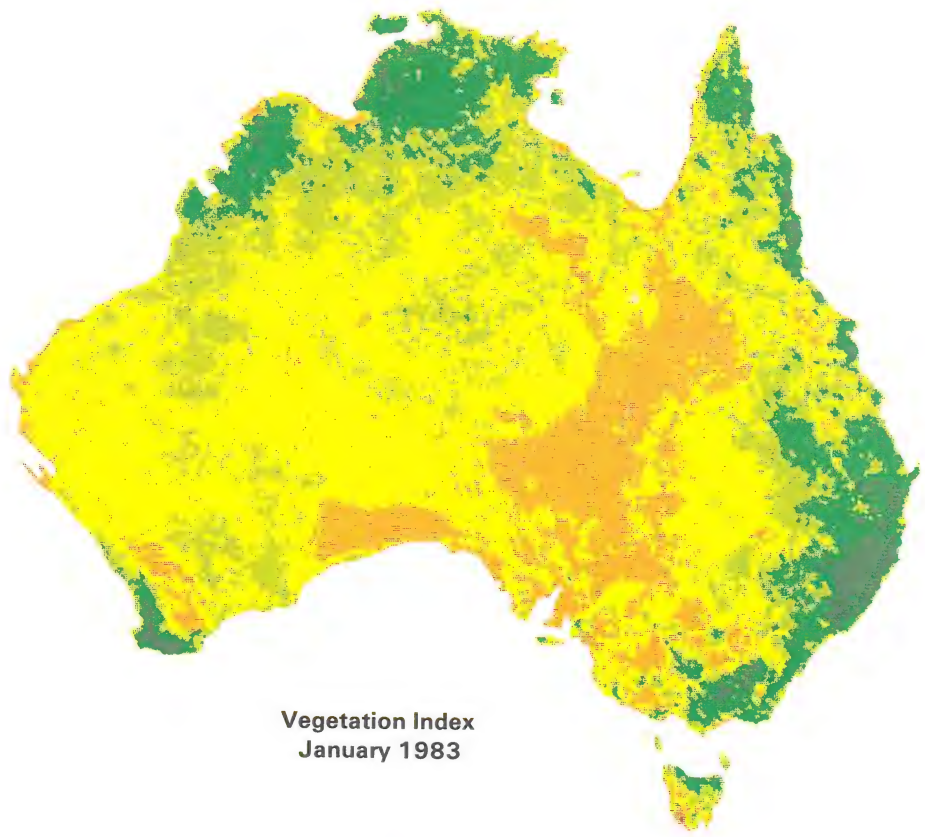
The amount and structure of the plant cover follows the overall gradient in precipitation in showing a decline towards the interior of the continent. Water availibity is the primary factor in the confinement of woodland and forest to the margins of the continent. It has also tended to concentrate most of the vegetation changes that have resulted from European settlement within these same areas, as can be seen by comparing the summary maps on pages 6 and 7. This pattern is greatly complicated by soil factors, including the distribution of heavy clay soils and of calcareous or saline soils. Elevation is of only limited significance, as Australia is a country of generally subdued relief.

The seasonal distribution and effectiveness of rainfall are also important determinants of the nature of vegetation. The occurrence of a summer maximum in the north and a winter maximum in the south has a major impact on the the growth and reproductive patterns of plants. It has given rise to separate monsoonal and mediterranean floristic elements within the vegetation.

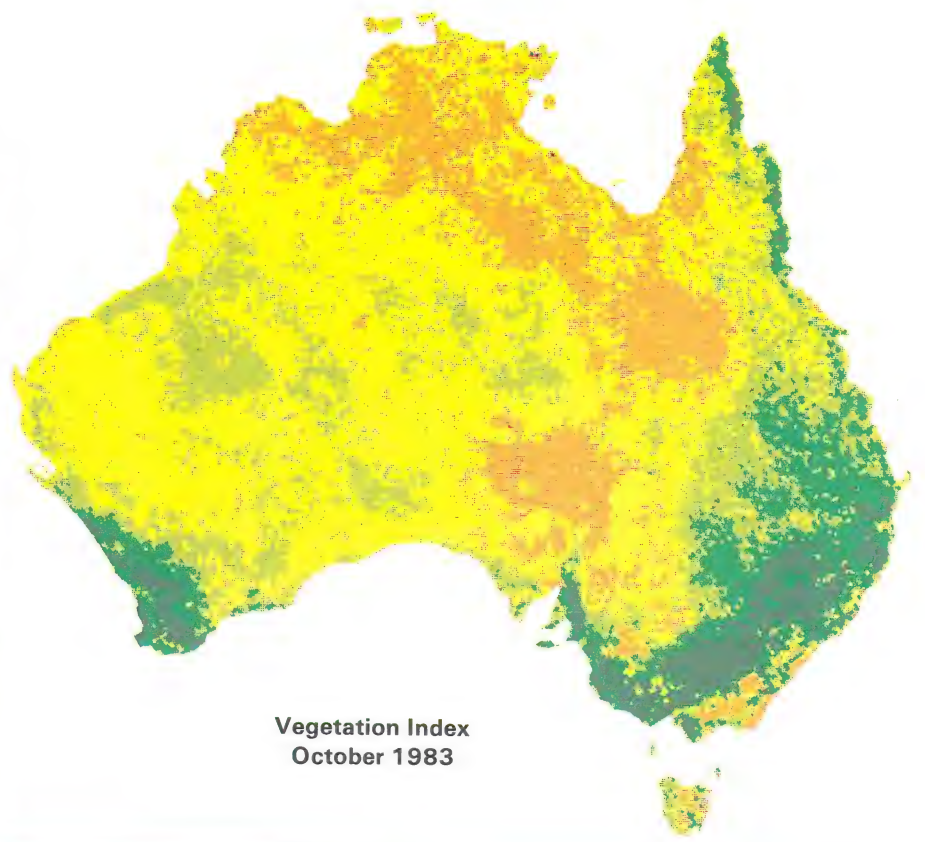
In global terms, Australia is an arid continent and its interior is only sparsely vegetated. But compared to other areas with similar rainfall Australia's deserts are well-vegetated, stabilised by a fluctuating cover of grasses and shrubs. That this vegetation cover is fragile and dependent upon the unreliable rains for its continuance is often demonstrated during a run of dry years. When it does rain across the inland the major vegetation change is the rapid growth of ephemerals, which carpet the landscape only to disappear again within months. These flushes of vegetation growth follow the general pattern of seasonal distribution of rainfall across the continent.

The marked seasonal fluctuations in the herbaceous vegetation have been intensified by European settlement, in particular through the establishment of sown pastures and seasonal crops. This is clearly recognisable on the satellite image maps on this page.

SEASONAL VEGETATION CHANGE



Vegetation Index
January 1983



Vegetation Index
October 1983

Contrasting wet and dry seasons in Kakadu National Park, NT
The top photograph shows the growth in understorey vegetation in January, the height of the 'wet' in the Top End. The same scene in October, near the end of the 'dry' (below), has virtually no herbaceous plant material.

The strong seasonal contrast in the availability of water for plant growth across Australia is clearly visible on this pair of satellite image maps. The maps were derived from data collected by the Advanced Very High Resolution Radiometer (AVHRR) instruments onboard the US National Oceanographic and Atospheric Administration (NOAA) series of meteorological satellites and they provide a measure of the amount of actively growing vegetation for January and for October 1983.

Known as Vegetation Index maps, they enhance that part of the total reflectance signal which is a response to the cover of live plant material. The satellite's scanners detect reflectance in a number of discrete wavelength bands within the electromagnetic spectrum. Vegetation indices are based on the ratio of the reflectance signals in the near infrared and the visible red parts of the spectrum. Where vegetation is dense and actively photosynthesising, the ratio of the signals (the vegetation index) will be greater. The index used to make these maps is termed the Normalised Difference Vegetation Index (NDVI).

Each of the maps is composed of a mosaic from a number of images taken over a week during the month, with cloudy pixels removed where possible. On the map for January, however, parts of coastal southeast Australia and Tasmania appear to have less plant cover than in reality, because cloud covered these areas during the entire week of sampling.

The colours range from dark green, indicating areas with the most abundant plant cover, through to red, where there is little or no actively growing vegetation. The vegetation index largely reflects changes in the growth of the herbaceous layer as this is where variations in the amount of green vegetation cover are most pronounced. Areas covered by dense evergreen trees and shrubs exhibit less seasonal variation.

The effects of the monsoon rains in January stand out clearly as a 'greening up' across northern Australia in contrast to the very sparse cover over these areas in October, the end of the dry season. The agricultural areas in the south-east and south-west display the highest index values on the October index map. This is the height of the growing season for wheat, other cereals and improved pastures after the winter rains across southern Australia.

Aboriginal

The plant cover of Australia might be regarded as approximating natural vegetation prior to European settlement (Carnahan 1986). Human influence was limited to the hunting and gathering activities of the Aboriginal population, and possibly to the beginnings of the domestication of plants (Hynes and Chase 1982).

Aboriginal burning regimes may have had very significant effects in many places, although it is true that fires caused by lightning are part of the natural environment of Australia. Interpretation of pollen and charcoal fragments from lake bed sediments suggests that this aspect of Aboriginal land use had an impact on the composition of vegetation communities over many thousands of years. The evidence of the Aboriginal use of fire is irrefutable, but the actual effects on vegetation are a matter of considerable debate (Nicholson 1981). In any case they were of a very different nature from the later European disturbance.

European

European settlement brought with it a range of land uses with a range of effects on the natural vegetation. Urban development has caused marked changes in the plant cover, but it directly affects little more than 0.1% of the land surface. To this must be added the area indirectly affected, as most cities are now surrounded by a belt of 'rural retreats'.

Commercial forestry takes various forms, including selective extraction of native timbers, clear-felling, and plantations using exotic species. These currently affect about 2% of the total area of the country.

Cropping and intensive animal production occupy less than 10% of the total area, concentrated mostly in the better watered parts of temperate Australia. These activities have required the removal of the native vegetation and the introduction and maintenance of exotic crop and pasture species under regimes of cultivation and intensive management.

The most widespread form of land use is extensive livestock grazing which affects about 60% of Australia. The obvious effects of pastoralism, namely changes in species composition and reduced cover, result from grazing, browsing, and trampling by sheep and cattle on a flora and vegetation that evolved in the absence of hoofed animals. These effects have been compounded by overgrazing, by the removal of some woody plants, by new patterns of burning, and by the deliberate or accidental introduction of a range of exotic plants and animals, notably rabbits. The only significant effects of Europeans on the rest of the country are from recreational activities and mining or mineral exploration in some locations.

The flora

The probable distribution of the major floristic groups of Australian vegetation immediately before European settlement is shown on the map below.

Native flora

The distinctive appearance of most Australian vegetation is due to the dominance of a few widespread genera. *Eucalyptus* or *Acacia* trees and shrubs dominate the natural vegetation over about 75% of the continent, and preserve its original character in many modified areas. Hummock grasses (*Triodia* and the closely related *Plectrachne*) form a prominent understorey in more than 25% of the vegetation.

There are more than 500 species of *Eucalyptus*, nearly all of which are endemic to Australia. Their crowns cast relatively little shade, as they have sparse foliage with vertically hanging leaves. Although *Acacia* is not confined to Australia, there are more than 700 native species. Most of these have a distinctive foliage consisting of flattened leaf stalks (phyllodes), which resemble simple leaves but tend to present their edge to the light.

The endemic genera *Triodia* and *Plectrachne* are members of the family Poaceae (formerly Gramineae). They exhibit the hummock grass growth form, with a mass of repeatedly branched stems bristling with long spine-like leaves giving the the appearance of a mound up to a metre or more in height. Hummock grassess are commonly called 'spinifex', a name that is liable to cause confusion with the botanical genus *Spinifex*, a creeping coastal grass.

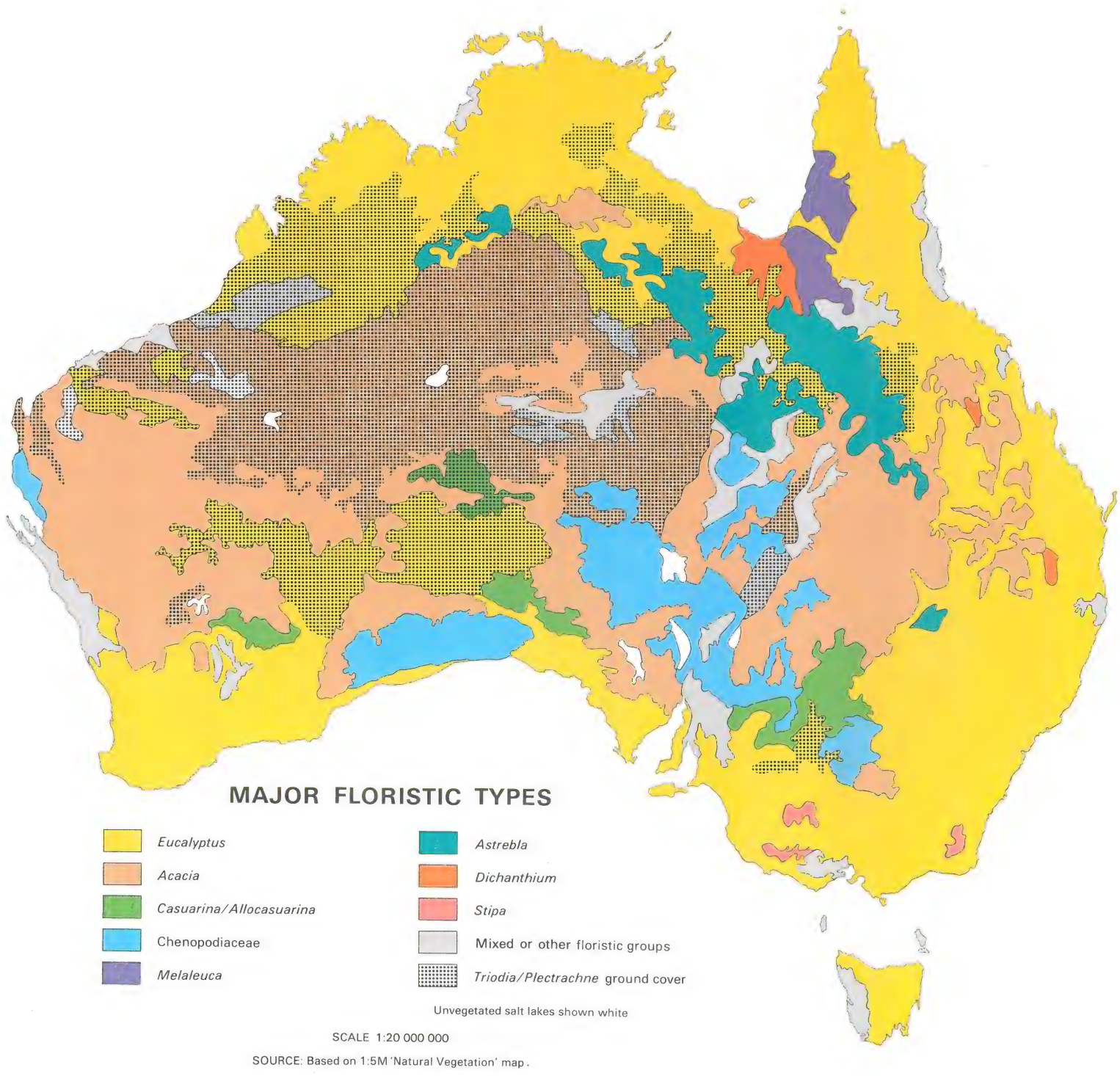
Some other spatially important elements of the flora are also distinctively Australian. *Casuarina* is a largely endemic genus of trees and shrubs in which the leaves are reduced to vestigial teeth and the slender branchlets function as leaves. Others, such as the low shrubs of the family Chenopodiaceae and the tussock grasses, have counterparts elsewhere.

Australian trees and shrubs are predominantly evergreen with hard and tough (sclerophyll) leaves that are often small or reduced; 'ordinary' (orthophyll) leaves are prominent only in moist forests. The hummock grasses too are evergreen perennials. Many of the herbaceous species are also perennials, but most of these lose some foliage seasonally, especially under lower and more erratic rainfall, where the proportion of annual or ephemeral species increases.

Introduced flora

The number of naturalised alien species in the present Australian flora stands at around 10% of the total of 20 000 species (Michael 1981). In terms of area occupied, the most important introduced plants are sown herbaceous species; namely winter or summer crops, especially cereals, and annual or perennial pasture grasses and legumes. The introduction of these plants has been accompanied by the introduction, both accidental and deliberate, of many species of herbaceous weeds.

There are more limited areas of a wide range of other introduced economic plants, such as horticultural areas, or plantations of sugar cane and of pine trees (chiefly *Pinus radiata*). Some introduced woody plants, both economic and ornamental, have escaped to become weeds in rural areas.



Classifying Australia's vegetation

While there are many possible ways to classify vegetation, the system adopted for the maps in this volume combines measures of the sizes and densities of plants to give specific meanings to terms such as forest, woodland and shrubland.

As most natural vegetation has identifiable layers, or 'strata', the structural forms of the top stratum are subdivided by the most significant layer of the understorey. The vegetation types are then identified by the genus or family of the dominant species.

This composite structural–floristic classification combines the structural types attributed to Specht (1970) with the notation used by Beard and Webb (1974) for their vegetation survey of WA. It is the same basic classification used for the map Natural Vegetation in the second series of this atlas (Carnahan 1976), but with some modifications to accommodate present vegetation. Comparable systems have been used for most of the recent small scale mapping of vegetation in Australia.

The diagram below shows how to interpret the code letters and numbers used to classify vegetation on the accompanying 1:5 million scale maps. It is important to recognise that the formal code for any mapping unit represents only a spatial generalisation as no stand of vegetation is ever entirely uniform.

The classification operates as a two-way table of eight growth form classes by four foliage cover classes, which define the principal structural forms—see the pictorial key opposite. Thus where medium height trees occur with a foliage cover of 10–30%, the vegetation is classed as woodland (**M2**). In the complete map codes the structural form of the top stratum and the growth form of the next tallest stratum with cover more than 10% are indicated, while lower case letters show the botanical type of the dominant plants. For example, **eL2Z** represents a *Eucalyptus* low woodland with an understorey of low shrubs.

Where the top stratum has a cover of less than 10%, the understorey becomes more conspicuous and is therefore also given a floristic code letter. Thus the code **eL1kZ** represents a *Eucalyptus* low open woodland over low chenopod shrubs.

Growth form is a simple description of plant structure whereby trees and shrubs are separated into several height classes. Tall shrubs (**S**) differ from low trees (**L**) in being multi-stemmed from or near the ground; where these two growth forms are mixed within a single layer the growth form is generalised as **L**. Hummock grasses, the 'spinifex' of the inland, are listed as a distinct growth form (**H**).

Herbaceous plants are divided into two groups. The first (**G**) comprises plants described as tussocky or tufted (that is having numerous erect stems or leaves arising from compact bases or from spreading rhizomes) and consists of grasses and graminoids (plants that are grass-like in form, such as sedges, but not of the family Poaceae, or grasses). It includes the native tussock grasses and graminoids, together with cereals, sugar cane, and some sown pasture grasses.

The second group (**F**) includes the forbs (herbaceous plants that are neither grasses nor grass-like in form) and the sward-forming grasses, which are not tussocky or tufted. Forbs are widespread in the native flora, and also among the pasture, crop, and weed plants of the introduced flora. The grasses and legumes in this category are creeping or spreading by nature, or else adopt this habit under grazing.

Foliage cover is expressed as 'projective foliage cover' (p.f.c.) for each stratum, and is the proportion of the ground that would be shaded if sunshine came from directly overhead—see photo above. Foliage cover differs from canopy cover, which is the proportion of ground that lies beneath the crowns of the plants, since it makes allowance for light passing between the leaves and branches of the canopy.

The four foliage cover classes are separated at 10%, 30% and 70% p.f.c. Foliage cover class 1 is specified as less than 10%, but if the cover in any stratum is less than 1%, as in the case of relic trees on cleared paddocks, it is considered to be negligible.

Floristic codes refer to the taxonomic group (typically a family or *genus*) of the dominant plants in any stratum. They are shown for the tallest stratum, and also for the next layer in cases where the cover of the upper stratum is less than 10%. The most common tree and shrub genera are *Eucalyptus* (**e**) and *Acacia*, or 'wattle' (**w**). The native *Callitris* and the introduced *Pinus* are grouped as conifers, or 'pine' (**p**).

Shrubs and forbs of the family Chenopodiaceae, notably of the genera *Atriplex* (saltbush), *Maireana* (bluebush) and *Sclerolaena*, are treated as a floristic unit (**k**). Other plant families coded are the herbaceous Asteraceae (formerly Compositae) (**z**) and Fabaceae (**f**), specifically the introduced pasture legumes *Trifolium* and *Medicago*.

The closely related hummock grass genera *Triodia* and *Plectrachne* are treated as a floristic unit (**t**). Tussock grass genera include the native *Astrebla* (**a**), *Dichanthium* (**d**) and *Stipa* (**s**), and the introduced *Saccharum*, or sugar cane (**v**). Grass genera not treated individually make up a residual group (**y**). All the families of graminoids, notably Cyperaceae (sedges), are grouped as a floristic unit (**g**).

If two floristic types are of about equal importance in a stratum then both codes are given, for example **eb** means that *Eucalyptus* and *Banksia* are co-dominant, the first code letter suggesting the slightly more abundant type. Where it is not possible to define one or two major floristic types, the floristic component is treated as 'mixed or other' (**x**).

Some herbaceous vegetation has a strictly seasonal occurrence. Living plants are present only during an annual or sporadic growing season and such vegetation is distinguished by italicised code characters (for example ***yF3***, ***wS1zF***). Seasonal crops are also in this category but on the Present Vegetation map are represented by symbols, generally overlain on grassland vegetation. This reflects the widespread practice of rotation of crops with pasture. In only a few areas, such as part of the Darling Downs in south-eastern Qld, is cropland devoted solely to cropping.

Foliage cover
Looking up into the canopy of a Eucalyptus *open forest* (**eM3L**). *The amount of sky blocked out by the leaves, stems and branches of this forest type averages more than 30%.*

READING THE VEGETATION CODES

Upper stratum — Lower stratum

wL1kZ

Example: **wL1kZ** = Acacia low trees, foliage cover less than 10% (Low open woodland), with an understorey of chenopod low shrubs (saltbush)

FLORISTIC CODES
(not shown for lower stratum if upper stratum foliage cover is greater than 10%)

- **a** *Astrebla* (Mitchell grass)
- **b** *Banksia*
- **c** *Casuarina* incl. *Allocasuarina*
- **d** *Dichanthium* (bluegrass)
- **e** *Eucalyptus*
- **f** Fabaceae (incl. clovers and medics)
- **g** Graminoids
- **h** *Hakea*
- **k** Chenopodiaceae
- **m** *Melaleuca*
- **n** *Nothofagus*
- **o** *Owenia* (desert walnut)
- **p** Conifers
- **q** *Myoporum* (sugarwood)
- **r** *Heterodendrum* (rosewood)
- **s** *Stipa*
- **t** *Triodia* and/or *Plectrachne*
- **v** *Saccharum* (sugar cane)
- **w** *Acacia* incl. *Racosperma*
- **x** Mixed or other
- **y** Other grasses
- **z** Asteraceae (daisies)

GROWTH FORM CODES

- **T** Tall Trees
- **M** Medium Trees
- **L** Low Trees
- **S** Tall Shrubs
- **Z** Low Shrubs
- **H** Hummock Grasses
- **G** Tussocky or Tufted Grasses and Graminoids
- **F** Other Herbaceous Plants

FOLIAGE COVER CODES
(only shown for upper stratum)

- **1** Less than 10%
- **2** 10–30%
- **3** 30–70%
- **4** Greater than 70%

NOTES

Underlined codes indicate interdune vegetation

Italicised codes indicate seasonal vegetation

The vegetation types shown on the two 1:5 million scale maps are illustrated here as diagrammatic cross-sections. They are arranged according to the growth form and foliage cover of the tallest stratum, as in the map legends, but with a commonly occurring understorey superimposed to give an actual mapped example of a subtype of each structural form. The examples illustrated are indicated by a map code shown in blue. Structural forms marked with an asterisk are not represented on the maps because their occurrence is either too restricted to be mapped at 1:5 million scale or else not easily separated from other structural forms.

PICTORIAL KEY TO THE STRUCTURAL FORMS OF AUSTRALIAN VEGETATION

GROWTH FORM OF TALLEST STRATUM	FOLIAGE COVER OF TALLEST STRATUM			
	Greater than 70%	30–70%	10–30%	Less than 10%
Tall Trees Greater than 30 metres (40 m, 30, 20, 10)	TALL CLOSED FOREST (T4) xT4	TALL OPEN FOREST (T3) eT3L	TALL WOODLAND (T2)* eT2M	
Medium Trees 10-30 metres (40 m, 30, 20, 10)	CLOSED FOREST (M4) xM4	OPEN FOREST (M3) eM3L	WOODLAND (M2) eM2S	OPEN WOODLAND (M1) eM1yG
Low Trees Less than 10 metres (15 m, 10, 5)	LOW CLOSED FOREST (L4) xL4	LOW OPEN FOREST (L3) wL3	LOW WOODLAND (L2) xL2G	LOW OPEN WOODLAND (L1) eL1yG
Tall Shrubs Greater than 2 metres (4 m, 2)	CLOSED SCRUB (S4)* xS4	OPEN SCRUB (S3) xS3Z	TALL SHRUBLAND (S2) eS2H	TALL OPEN SHRUBLAND (S1) wS1yG
Low Shrubs Less than 2 metres (2 m, 1)	CLOSED HEATH (Z4)* xZ4	OPEN HEATH (Z3) xZ3	LOW SHRUBLAND (Z2) kZ2G	LOW OPEN SHRUBLAND (Z1) wZ1
Hummock Grasses (1 m, 0.5)			HUMMOCK GRASSLAND (H2) tH2	
Tussocky or Tufted Grasses and Graminoids (1 m, 0.5)	CLOSED TUSSOCK GRASSLAND OR CLOSED SEDGELAND (G4) gyG4	TUSSOCK GRASSLAND OR SEDGELAND (G3) yG3	OPEN TUSSOCK GRASSLAND (G2) aG2	SPARSE OPEN TUSSOCK GRASSLAND (G1) yG1
Other Herbaceous Plants (1 m, 0.5)	DENSE SOWN PASTURE (F4) yfF4	SOWN PASTURE (F3) yfF3	OPEN HERBFIELD (F2)* xF2	SPARSE OPEN HERBFIELD (F1) kF1

NOTES

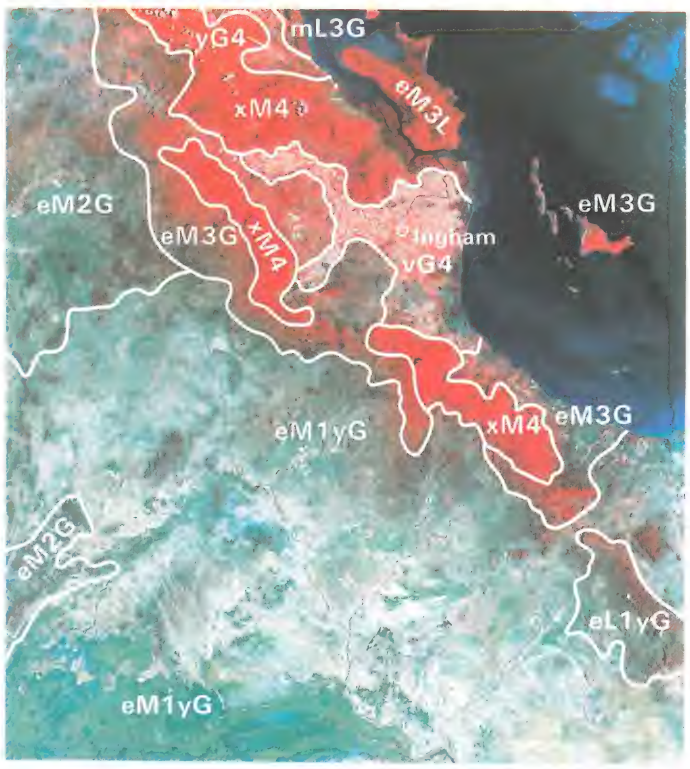
Each structural form is illustrated by a characteristic vegetation type. The map code for each example is printed in blue.

* This structural form only occurs in areas too small to be mapped at 1:5 million scale.

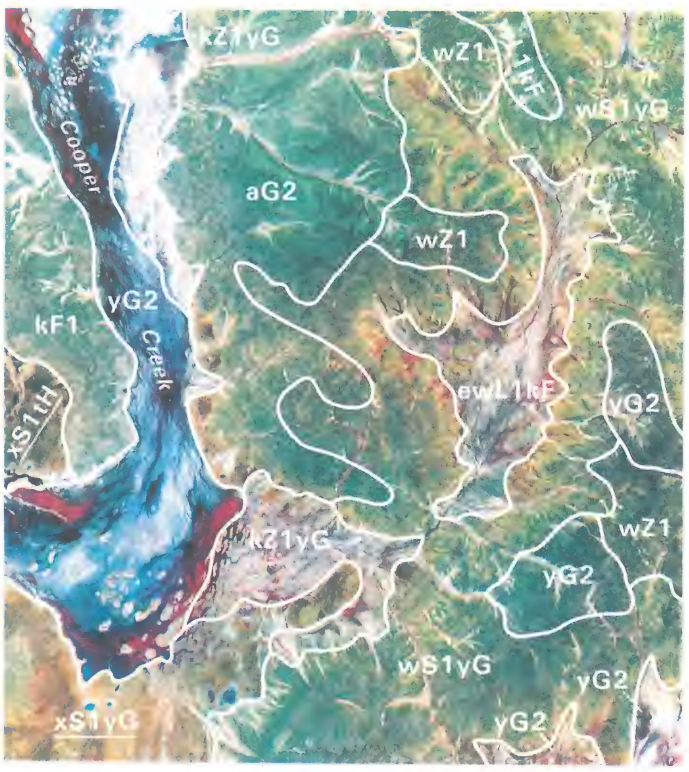
Nomenclature based on Specht (1970).

Mapping a continent's vegetation

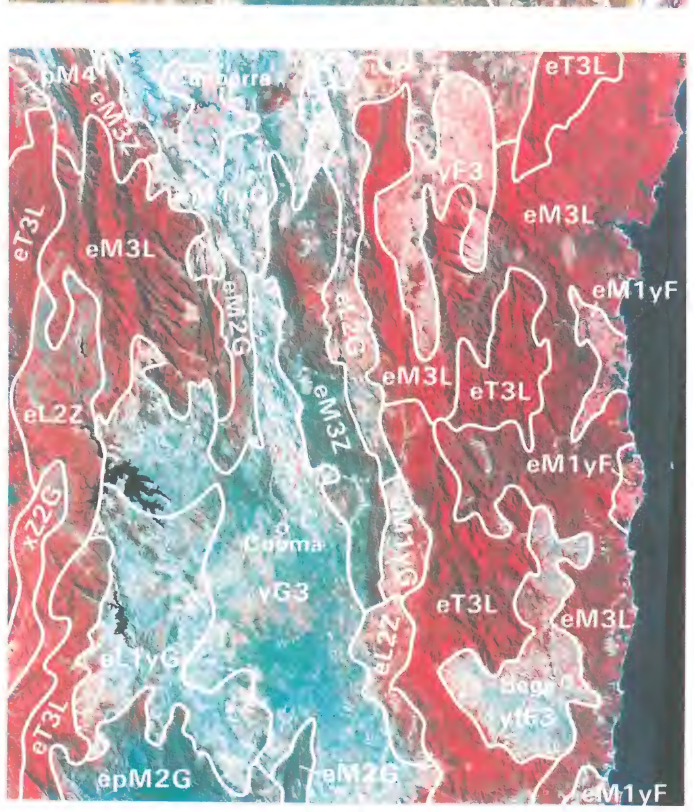
Rainforests and canelands
The sugar cane growing areas of the lowlands around Ingham on the northern Qld coast, coded as **vG4**, *stand out in strong contrast to the solid red signal of the rainforests of the coastal ranges (***xM4***). The eucalypt open forest on Hinchinbrook Island (***eM3L***) contains many patches of rainforest and therefore has a similar bright red signal. The sparse, dry season cover of the open woodlands (***eM1yG***) has a patchy white and blue signal, mainly attributable to the underlying soil and rock outcrops. Between the rainforests and the open woodlands is a narrow transitional zone of eucalypt open forest (***eM3G***).*



The Channel Country
*This image shows Cooper Creek, southwestern Qld, near where it swings westward into SA. The floodplain appears as a broad blue band crossed by a network of channels. The open grassland coding (***yG2***) describes the average condition of the vegetation of the Channel Country, which fluctuates markedly in response to the passing of floodwaters. This can be seen by the red areas, which indicate localised flushes of dense ephemeral plants. The low hills of the rolling downs, here a greenish-yellow, carry a sparse shrubland (***wS1yG***, ***wZ1***) and sparse grasses, while the plains (***aG2***) represent the southern arid extensions of the Mitchell grass country.*



The Monaro
*The NSW Southern Tablelands town of Cooma is at the centre of this image, with the Canberra urban area at the top and Bega at the bottom right. The naturally treeless Monaro plains (***yG3***), south of Cooma, appear light blue, as do other grassland areas further north. Pastures along the coast are pink, primarily as a result of higher rainfall. There are distinct boundaries between the natural forests, which appear red, and the cleared lands. The bulk of the* Eucalyptus *forests are in the* **eM3L** *category, while the bulk of the tall forests (***eT3L***) have the brightest signal. The drier forests (***eM3Z***) and the woodlands (***eM2G***) appear blue-brown.*



The mapping of Australia's present vegetation at 1:5 million scale, on which this volume is based, was made possible by the rapid improvements in earth resources satellite technology over the last decade.

When the first multispectral scanner (MSS) imagery was received from the ERTS-1 (later renamed Landsat 1) satellite, launched in 1972, its potential for identifying the present boundaries of vegetation and land clearance was soon realised. But it was not until Australia established its own Landsat receiving station at Alice Springs in 1979 that suitable satellite imagery became readily available and easily selected. Subsequent improvements in image processing and the standardisation of false colour transparency production made possible a simple methodology for mapping vegetation boundaries over the entire continent.

Compiling the maps

Present Vegetation

The 1:5 million scale map of present vegetation shows the state of Australia's plant cover in the mid-1980s for both native and exotic species. Such mapping in effect freezes a dynamic situation because plant cover in many areas is constantly changing in response to climatic factors and human activities. Therefore, all that can be done is to indicate the 'average' condition of the vegetation over a period of several years.

Compilation of the map was based on standard false-colour composite transparencies of Landsat imagery at 1:1 million scale. The multispectral scanner on board the satellite records spectral reflectance values received from the earth's surface in several discrete wavelength bands. As the major terrestrial influences on the total reflectance in these bands are vegetation, soils and rock, so spatial differences in such features are visibly distinct on the imagery.

The transparencies used were selected from images recorded over the period 1980–85. The boundaries of spectral features visible on each image were plotted on to overlays and then transferred to a base map at 1:1 million scale. At this stage many of the smaller units were grouped according to other information on the vegetation of each area and were generalised so that only those likely to survive reduction to the publication scale of 1:5 million were retained.

Over much of Australia where plant cover is sparse, vegetation contributes only a small part to the total reflectance signal. The map units distinguished in these areas are in fact terrain patterns, the reflectance of which may be related to landforms, soil or rock, as well as vegetation. A premise of this project, therefore, was that there is a general spatial correlation between the physical features of the environment (such as topography and soil) and natural vegetation.

Where European land use has supplanted tracts of natural vegetation, there are large differences in reflectance between the natural and modified land cover. These abrupt changes in reflectance are significant vegetation boundaries. In addition, some widespread natural vegetation types were found to be consistently associated with distinctive spectral signatures on Landsat. Notable among these were the rainforests and open forests, and the *Acacia* and mallee shrublands.

Reflectance patterns may suggest the nature of vegetation in many areas, but comprehensive information from the ground is required to draw meaningful boundaries. It was necessary to collect and evaluate all available information about the vegetation within each of the mapped units. This included published and unpublished maps of vegetation, soils, land use and land systems, together with associated texts and other relevant reports.

Information on crops and pastures was taken from the statistical reports of the Agricultural Data Dissemination Service (ADDS), based on annual agricultural censuses (Australian Bureau of Statistics 1982–85). Interpretation of some areas was aided by examining topographic maps and aerial photographs, and by field studies.

With this information in hand, decisions were made on the vegetation type within each plotted unit, and this was translated into a code within the structural and floristic terms of the classification.

Mapping from space

Satellite imagery, with its regular and up-to-date coverage of the entire continent, proved to be the most logical and economical means of mapping Australia's present vegetation. The Landsat MSS has spectral bands designed to detect vegetation, and the resolution of its images is ideally suited to small scale mapping. The width of the scanning path of Landsat is 185 km and each full image covers more than 30 000 km^2. Even so, with a continental area of 7.68 million km^2, the Present Vegetation map proved to be a major undertaking and about 450 images were required for total coverage of Australia.

Six examples of Landsat MSS false-colour images used as the primary mapping source for present vegetation are given to show the diversity of land cover patterns encountered across the continent. These im-

Natural Vegetation

The 1:5 million map of the natural vegetation is a reconstruction of the probable state of Australia's plant cover immediately before European settlement began in 1788. The Present Vegetation map was used as the starting point and it was then necessary to examine all available sources of information that might give a lead to the nature of the pre-settlement vegetation. These included historical records, maps based on original vegetation, and soil maps of cleared areas. One major source was the map Natural Vegetation in the second series of this atlas (Carnahan 1976). This earlier attempt at reconstructing natural vegetation had used all known source materials then available.

An important supplement to the 1976 map was the considerable amount of new mapping of reconstructed natural vegetation that has since become available for various sections of the country. Much of this new information was obtained from government and other authorities involved in environmental surveying and mapping, and the quality and coverage of the more recent work enabled a more accurate picture of the vegetation than was possible with the earlier map.

Generalisation

Spatial patterns in nature are never entirely uniform and it is therefore difficult to describe vegetation by a single classification code at any scale of observation. For a map at 1:5 million scale, where the smallest areas that can readily be distinguished are about 30 000 ha, the problems of generalisation for both codes and boundaries become more acute.

The compilation of the maps presented many of the general problems associated with vegetation mapping. Firstly, it is difficult to establish precise boundaries because vegetation types often merge into each other. Secondly, it is difficult to define the vegetation of a site where there are marked fluctuations in structure or composition, for example in response to runs of wet or dry years and to fires. As a result, it is necessary to generalise over both time and space by defining the 'average' condition of the vegetation of a given area over a period of several years.

The constraints of scale also made it necessary to map mosaics of vegetation types in terms of the spatially predominant type, though certain kinds of mosaic have been specially treated. Probably the most widespread vegetation mosaic is that associated with dunefields in inland Australia. Here, the vegetation on the crests may be different from that on the interdune areas and slopes. The areally dominant vegetation, that of the interdunes and stable lower dune slopes, is given in the coding (e.g. **wS1tH**), which is underlined to indicate that it is within a dunefield mosaic.

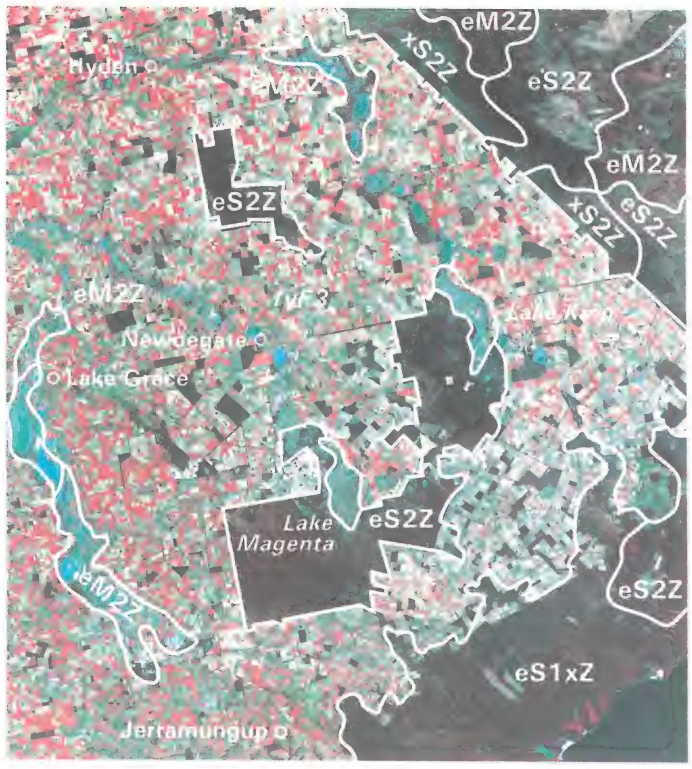
Intertidal mosaics of mangrove stands, low shrublands, herbaceous communities and bare salt flats occur at many places along the Australian coast. They cannot readily be separated in terms of predominant structural and floristic elements at 1:5 million scale and are therefore mapped and described as a 'littoral complex'. Urban and horticultural areas, with their varied cultural vegetation components, are also mapped as complexes. On the other hand, there is no separate treatment of certain other special environmental situations, such as wetland and alpine habitats; these are referred to in the descriptions of the different structural forms that occur in these habitats.

Mappable areas of rainforest are shown as either mixed closed forest (**xT4**, **xM4**) or *Nothofagus* closed forest (**nM4**), but smaller patches of rainforest frequently occur within open forest areas. Because of the current public and scientific interest in rainforest, the location of patches too small to map separately (but locally covering 500 ha or more) is indicated by symbols.

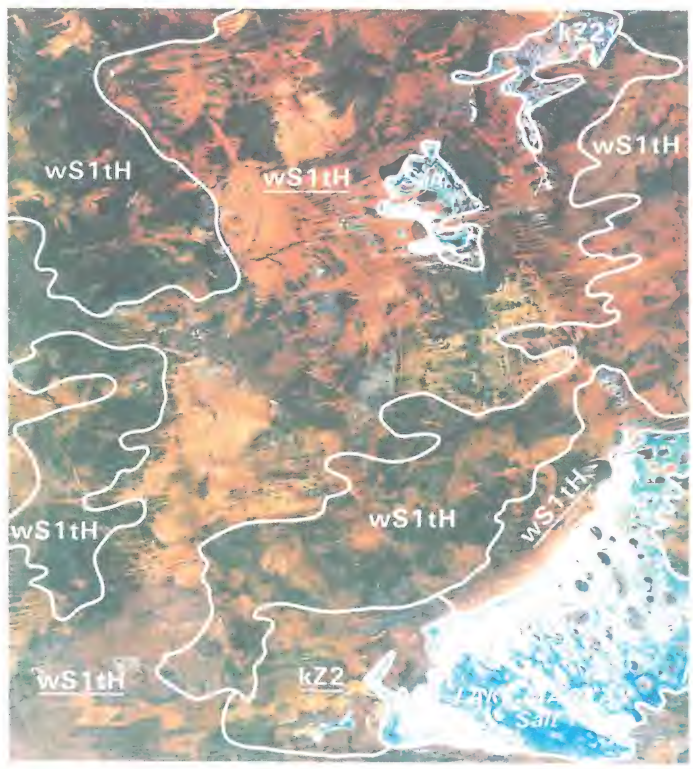
Except in relatively limited areas, seasonal cropping is conducted in association with livestock grazing and the vegetation consists of a mosaic of crop and pasture paddocks. Since the seasonal crops constitute a very distinctive kind of vegetation, being sown and harvested each year, the problem of mapping this mosiac has been overcome by using overprinted symbols. Crop symbols are area-related (1 per 10 000 ha) and are divided into summer (triangles) and winter (circles) crops. Their placement is based primarily on ADDS reports.

ages are produced by representing the reflectance values of three of the four spectral bands by the primary photographic colours of blue, green and red.

The high chlorophyll reflectance in the near-infrared part of the spectrum appears as red on the images, so areas of dense, vigorously growing vegetation show up as bright red. Dense sclerophyll vegetation often appears dark brown, largely because the bright signal of the underlying soil in the other bands is masked out by branches, leaves and litter. Fertilised and irrigated pasture appears as bright pink, while dry grassland is more often a pale blue colour. Exposed clay-based soils usually appear blue to white, while those formed on sand are more yellow, though both will appear much darker if they are wet. Imagery from early in the dry season generally gives the greatest contrast between the signals of the different vegetation types.



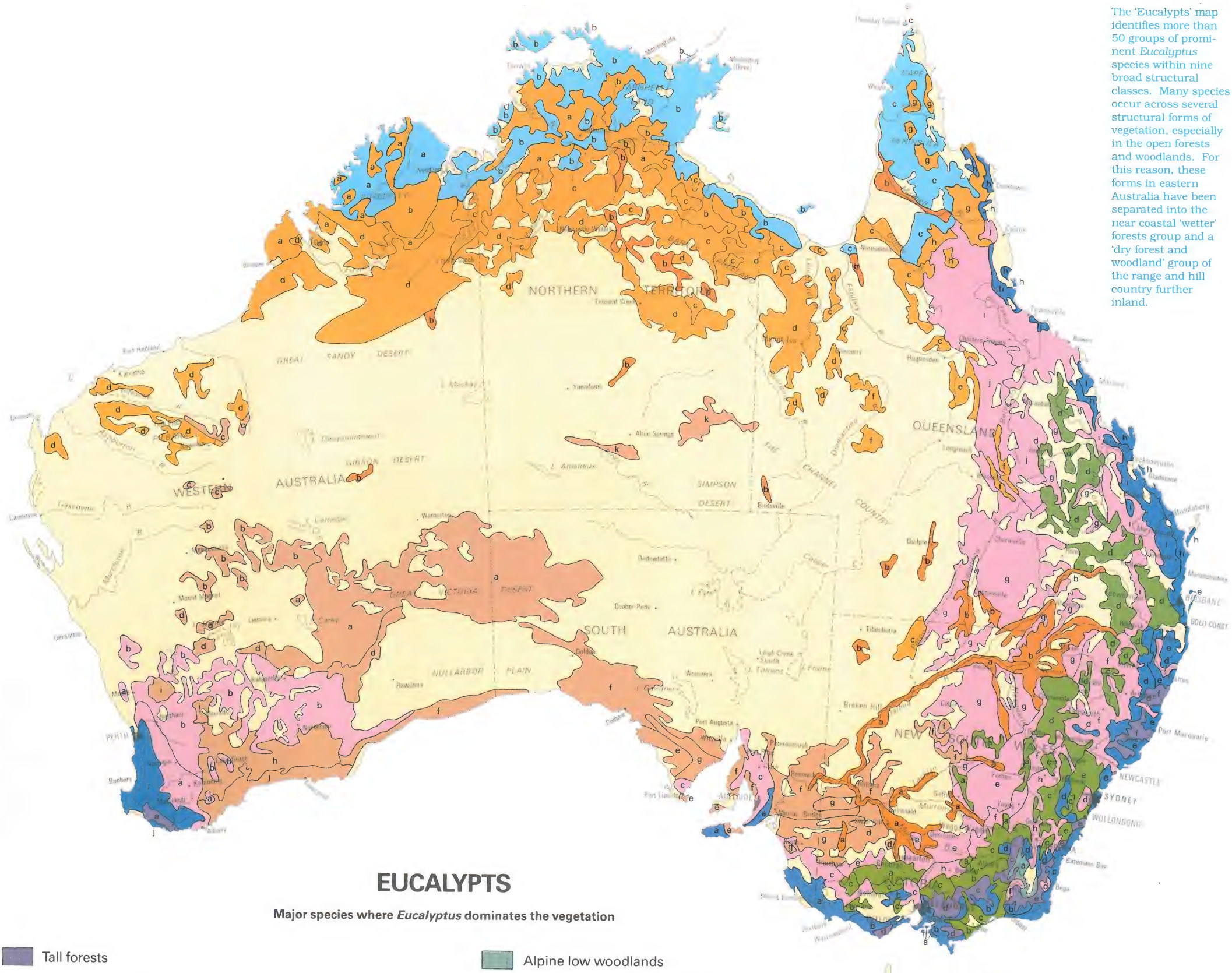
Western Australian wheatbelt
*This image shows the eastern margin of the wheatbelt in WA. The most striking feature is the sharp boundary between the cleared cropland, with its distinctive patchwork pattern of fields, and the uncleared bush, mainly mallee shrubland (**eS2Z**, **eS1xZ**). This image post-dates that used to compile the 1:5 million map and since then the boundaries of land clearance have moved further into former bushland areas. The chains of salt lakes with intervening areas of woodland are coded as **eM2Z**. The larger lake beds (Lake Grace, Lake Magenta and Lake King) are bare. Fire scars are visible as paler areas within the dark natural vegetation.*



Lake Mackay
*The mosaic of different aged fire scars, exposing varying amounts of the underlying soil, creates a patchy signal on Landsat imagery and is typical of wide areas of desert sandplain and dunefield in inland Australia. This pattern of dark and light areas indicates mostly transient differences in vegetation cover, which is constantly changing with regrowth after fires. The major mapped units are the dunefields, with visible linear dunes, and sandplains (**wS1tH**). The vegetation of both is similar: open shrublands, with Acacia dominant, over hummock grasses. The underlined codes indicate the vegetation of the stable interdune areas.*

Cobourg Peninsula
*The dominant vegetation is open forest (**eM3L**), which has a uniform red-brown signal. After burning it appears more blue or black. Woodlands (**eM2G**) generally occur further inland and are a lighter blue-brown colour. The rocky outcrops of the northern tip of the Arnhem Land escarpment show up as pale blue areas along the eastern side of the scene. The seasonally inundated floodplains of the major rivers are vegetated primarily by dense sedgelands (**gG4**). The large littoral area on the peninsula demonstrates the variety of cover types within this complex, with both dense mangrove forest (red areas) and bare mud flats (pale blue) occurring together.*

Australia's plant symbols



EUCALYPTS

Major species where *Eucalyptus* dominates the vegetation

Tall forests

a Karri—*E. diversicolor*
b Messmate Stringybark—*E. obliqua, E. nitida*
c Alpine Ash/Mountain Gum—*E. delegatensis, E. dalrympleana*
d Mountain Ash—*E. regnans*
e Brown Barrel/Manna Gum—*E. fastigata, E. viminalis*
f White Mahogany/Grey Gum/Tallowwood—*E. acmenoides, E.propinqua, E. microcorys*

Wet forests

a Brown Stringybark—*E. baxteri, E. obliqua, E. viminalis*
b Messmate Stringybark/Mountain Grey Gum—*E. obliqua, E. cypellocarpa*
c Silvertop Ash/White Stringybark—*E. sieberi, E. globoidea, E. gummifera, E. botryoides*
d Manna Gum—*E. viminalis, E. pauciflora, E. fastigata, E. andrewsii* (North), *E. laevopinea* (North)
e Blackbutt/Grey Gum/Sydney Blue Gum—*E. pilularis, E. propinqua, E. saligna, E. resinifera, E. maculata*
f Black Peppermint/Snow Gum—*E. amygdalina, E. pauciflora, E. rodwayi*
g Tasmanian Blue Gum/White Peppermint—*E. globulus, E. pulchella*
h Pink Bloodwood—*E. intermedia, E. acmenoides, E. microcorys* (South), *E. pellita* (North), *E. exserta*
i Forest Red Gum/Carbeen—*E. tereticornis, E. tessellaris, E. maculata, E. citriodora*
j Jarrah/Marri—*E. marginata, E. calophylla*

Dry forests and woodlands of the ranges

a Red Ironbark—*E. sideroxylon, E. dealbata*
b Candlebark/Narrowleaf Peppermint—*E. rubida, E. radiata, E. dives, E. viminalis*
c Red Stringybark/Broadleaf Peppermint—*E. macrorhyncha, E. dives, E. rossii* (NSW)
d Narrowleaf Ironbark—*E. crebra, E. fibrosa, E. drepanophylla* (Qld), *E. tessellaris, E. trachyphloia, E. melanophloia*
e Red Bloodwood/Grey Gum—*E. gummifera, E. punctata, E. piperita, E. dives*

Woodlands

a Wandoo/York Gum—*E. wandoo, E. loxophleba*
b Salmon Gum—*E. salmonophloia, E. loxophleba*
c Yellow Gum/Peppermint Box—*E. leucoxylon, E. odorata* (SA), *E. camaldulensis* (Vic.)
d Forest Red Gum—*E. tereticornis, E. moluccana*
e Grey Box—*E. microcarpa*
f White Box—*E. albens, E. melliodora*
g Poplar Box—*E. populnea, E. intertexta* (South), *E. melanophloia* (North)
h Yellow Box/Blakely's Red Gum—*E. melliodora, E. blakelyi*
i Narrowleaf Ironbark—*E. crebra, E. drepanophylla, E. alba, E. papuana, E. tessellaris*
j Silverleaf Ironbark—*E. melanophloia*
k Manna Gum—*E. viminalis*

Alpine low woodlands

a Snow Gum/Black Sallee—*E. pauciflora, E. stellulata*
b Tasmanian Snow Gum/Cider Gum—*E. coccifera, E. gunnii*

Mallees

a Ooldea Mallee/Desert Gum—*E. youngiana, E. gongylocarpa*[1]
b Kingsmill's Mallee—*E. kingsmillii*
c Blue Mallee—*E. gamophylla*
d Giant Mallee/White Mallee—*E. oleosa, E. dumosa* (East)
e Soap Mallee—*E. diversifolia*
f Red Mallee/Yorrell—*E. socialis, E. gracilis, E. dumosa*
g Ridge-fruited Mallee/Narrowleaf Red Mallee—*E. incrassata, E. foecunda*
h Mallee—*E. eremophila*
i Narrowleaf Red Mallee/Redwood—*E. foecunda, E. transcontinentalis, E. sheathiana*
j Tallerack—*E. tetragona*
k Red bud Mallee—*E. pachyphylla*

Northern forests and woodlands

a Variable-barked Bloodwood/Darwin Stringybark—*E. dichromophloia*[2], *E. tetrodonta, E. setosa*
b Darwin Stringybark/Darwin Woollybutt—*E. tetrodonta, E. miniata*
c Darwin Stringybark/Longfruit Bloodwood—*E. tetrodonta, E. polycarpa*

Northern low woodlands

a Darwin Box—*E. tectifica, E. foelscheana, E. ptychocarpa, E. confertiflora, E. grandifolia*
b Scarlet Gum/Rusty Bloodwood—*E. phoenicea, E. ferruginea, E. bleeseri, E. aspera*
c Pale Bloodwood/Silverleaf Box—*E. terminalis, E. pruinosa, E. argillacea*
d Snappy Gum/Migum—*E. brevifolia, E. leucophloia, E. setosa, E. dichromophloia*
e Yellow Jacket/Ghost Gum—*E. similis, E. papuana, E. whitei*
f Mountain Yapunyah—*E. thozetiana, E. terminalis, E. normantonensis*
g Cullen's Ironbark/Molloy Red Box—*E. cullenii, E. leptophleba, E. alba*

Forests and woodlands of the inland floodplains

a River Red Gum/Black Box—*E. camaldulensis, E. largiflorens*
b Coolibah—*E. microtheca*

[1] low tree
[2] taxonomic complex

SCALE 1:15 000 000

SOURCE: Based on information used to compile the 1: 5 million map 'Natural Vegetation'.

The 'Eucalypts' map identifies more than 50 groups of prominent *Eucalyptus* species within nine broad structural classes. Many species occur across several structural forms of vegetation, especially in the open forests and woodlands. For this reason, these forms in eastern Australia have been separated into the near coastal 'wetter' forests group and a 'dry forest and woodland' group of the range and hill country further inland.

The complexity of eucalypt distributions is exemplified on the map by the number of widespread species—such as *E. viminalis*, the manna gum—which occur in more than one structural type and in several species groups. Widespread species also often have different associates at opposite ends of their range. Species followed by a state or region in the legend have a limited distribution within the wider mapped area of the major species. Common names are given for regionally important species, the more widespread appearing first. While many widespread or locally dominant species do not appear on the map, some 100 species, roughly 20% of the total, are included.

Eucalypts and acacias

Two dominant elements of Australia's vegetation—*Eucalyptus* and *Acacia*—occur right across the continent. They are to be found in almost all possible habitats—from the alps to coastal heaths and from the deserts to wet forests. These two genera between them dominate the top stratum of the vegetation over three-quarters of Australia. Despite this apparent uniformity, a closer look reveals a remarkable diversity even within these common generic groups.

These two maps identify species which are characteristic of the areas dominated by *Eucalyptus* and *Acacia* on the 1:5 million scale map of natural vegetation. They show the most prominent species, or groups of species, for all areas where '**e**' or '**w**' appear in the codes on that map. Although these genera do occur elsewhere, they are not the major floristic type of the vegetation within the unclassed areas.

The maps are not intended as species distribution maps as most of the boundaries come directly from the map of natural vegetation structure. The species named are those identified as dominant in each map unit, but most also occur outside these areas. There are also large overlaps in the ranges of individual species. However, the vegetation within the areas mapped is well described by the major species, such as 'poplar box' country or 'mulga' country.

In the inland areas where *Acacia* is the primary floristic type, a few (and often only a single) species clearly predominate. In the *Eucalyptus* forests, on the other hand, the tree species often overlap in intricate spatial distributions governed by the complex topography, soils and microclimate of the coasts and ranges. Nearly every map unit of the natural vegetation in the south-east contained several *Eucalyptus* species associations.

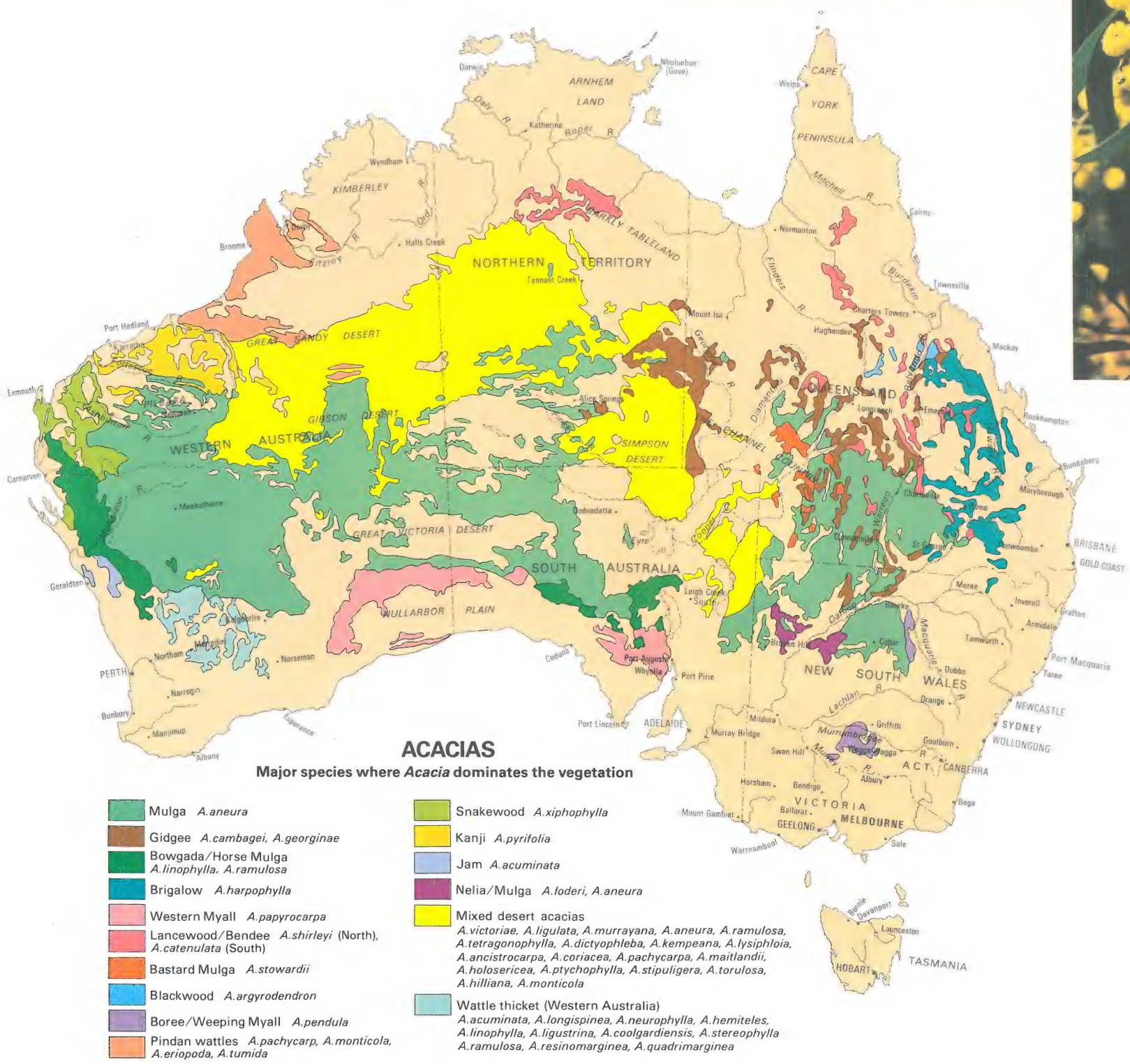
Gum tree flowers
More than any other plant, the gum tree is associated with the Australian bush. Eucalyptus *is an Australian genus of over 500 species, but a few also occur on islands to the north of Australia. The distinctive features of all eucalypts can be seen in this photograph—the mass of stamens, the capped buds and the woody fruits (gumnuts). The leaves generally have a tough waxy cuticle and contain numerous oil glands. There is a variety of rough-barked types (e.g. ironbarks, stringybarks and boxes) as well as the smooth-barked gums. The success of the eucalypts in Australia is now being mirrored overseas, where they have been widely planted.*

Acacia occurs elsewhere, notably in Africa, but the largest number and greatest diversity of the species are found in Australia, so it is rightly considered a symbol of Australia.

As the map clearly demonstrates, very large areas are dominated by *Acacia*. But there are some widespread and familiar species, particularly in south-eastern Australia, which do not appear because they generally occur as an understorey to *Eucalyptus* forests and woodlands. Some of the species which are shown, such as brigalow (*A. harpophylla*) and boree or weeping myall (*A. pendula*), no longer occupy their entire mapped range, which is based on natural vegetation.

Recent taxonomic work on the genus has suggested that most of the species currently assigned to *Acacia* should, by historical precedent, be more correctly known as *Racosperma* (Pedley 1986).

Golden wattle
The golden wattle flower (Acacia pycnantha) *is Australia's floral emblem* and Acacia *is the botanical name given to the many different plants which bear this distinctive flower type. Australia has over 700 named species of* Acacia, *displaying such a diversity of leaf forms and growth habits that many appear to be totally unrelated when they are not in flower. Leaf shape and size varies from the feathery, bipinnate leaves of many eastern understorey species to the leathery or spiny leaf-like phyllodes of most inland trees and shrubs. Phyllodes are the mature foliage of all species included on the 'Acacias' map.*



ACACIAS

Major species where *Acacia* dominates the vegetation

- Mulga *A.aneura*
- Gidgee *A.cambagei, A.georginae*
- Bowgada/Horse Mulga *A.linophylla, A.ramulosa*
- Brigalow *A.harpophylla*
- Western Myall *A.papyrocarpa*
- Lancewood/Bendee *A.shirleyi* (North), *A.catenulata* (South)
- Bastard Mulga *A.stowardii*
- Blackwood *A.argyrodendron*
- Boree/Weeping Myall *A.pendula*
- Pindan wattles *A.pachycarp, A.monticola, A.eriopoda, A.tumida*
- Snakewood *A.xiphophylla*
- Kanji *A.pyrifolia*
- Jam *A.acuminata*
- Nelia/Mulga *A.loderi, A.aneura*
- Mixed desert acacias *A.victoriae, A.ligulata, A.murrayana, A.aneura, A.ramulosa, A.tetragonophylla, A.dictyophleba, A.kempeana, A.lysiphloia, A.ancistrocarpa, A.coriacea, A.pachycarpa, A.maitlandii, A.holosericea, A.ptychophylla, A.stipuligera, A.torulosa, A.hilliana, A.monticola*
- Wattle thicket (Western Australia) *A.acuminata, A.longispinea, A.neurophylla, A.hemiteles, A.linophylla, A.ligustrina, A.coolgardiensis, A.stereophylla A.ramulosa, A.resinomarginea, A.quadrimarginea*

SCALE 1:20 000 000

SOURCE: Based on information used to compile the 1: 5 million map 'Natural Vegetation'.

The variety of vegetation types

The following section provides descriptions of each of the vegetation types shown on the two 1:5 million scale maps—'Natural Vegetation' and 'Present Vegetation'—accompanying this volume. The structural forms of the vegetation classification are grouped according to growth form, with the nomenclature of Specht (1970) indicated in the headings. The subforms, defined by the type of understorey, are arranged under subheadings, while the vegetation types are distinguished floristically (mostly by genus or family). The littoral, horticultural and urban vegetation complexes are covered separately.

Each vegetation type is described in the context of historical changes in its distribution, with some comment on environmental relationships. Maps in the other volumes of this atlas enable comparison of vegetation distribution with other physical and cultural aspects of the Australian environment such as climate, soils and land use.

In general, botanical names are used because common plant names are often a source of confusion. However, recommended common names for plants referred to in the text are listed in the 'Index of Common Names' on page 62.

Small summary maps at 1:30 million scale show how the distribution of each vegetation form has changed over the past 200 years. They show the areas where vegetation is structurally unchanged and where it is now different from the natural vegetation. These maps were derived from the analysis of digital versions of the two 1:5 million scale maps using a computerised geographic information system. The spatial data on vegetation structure were resampled into 4 x 4 km grid cells and overlayed to quantify and map the changes. The resultant area estimates are subject to the limitations of this technique and for vegetation classes which cover small areas the figures are only approximate.

Most of the small maps which show the extent of well known vegetation types or species were compiled directly from the Natural Vegetation map, as floristic types commonly cross the boundaries of several structural forms.

Tall trees

Tall closed forest

Trees >30 m high; >70% foliage cover **T4**

These magnificent forests, which survive today as only a few scattered relics in north-eastern Qld, represent the Australian equivalent of the tall tropical lowland rainforests of the Amazon and Zaire basins. With a height of up to 40 m or more and a dense closed canopy allowing very little light penetration, their 'cathedral like' atmosphere is both inspiring and belittling to human visitors. These forests are also among the most complex ecosystems on earth.

This structural form is represented by the tallest examples of the forests loosely known as 'rainforest'. Tall closed forest is shown only on the Natural Vegetation map. It previously occupied extensive areas of the rich alluvial and basaltic coastal lowlands in the Innisfail area of north-eastern Qld. Today only small fragments survive in this area, as much of this forest type has been almost entirely cleared for plantations of sugar cane (**vG4**).

The mapped former stand of tall closed forest (**xT4**) is considered by Tracey (1982) as the optimum development of rainforest in Australia under the most favourable conditions of climate and soil on the tropical humid lowlands. Tracey categorised this type as 'complex mesophyll vine forest' (see table below) consisting of a large number of species and having a very complex structure that involves a range of tree heights (up to 40 m or more).

Many specialised growth forms are present in tall closed forests. Vines are visually prominent on the canopy trees, and most trees have large (mesophyll) leaves. Because of its complexity, tall closed forest is mapped simply as **xT4** without reference to subforms.

Most rainforest types are mapped as **xM4** (discussed on page 20). These rainforests, particularly in Qld, do contain patches which exceed 30 m in height (Tracey and Webb 1975, Tracey 1982) but they are not readily separable at the scale of the map.

Where rainforest and sugar cane meet
*Looking from the Walter Hill Range, north of Tully (Qld), on to cleared agricultural lowlands. The rich soils of the sugar cane fields formerly supported rainforests over 30 m high (**xT4**). Only remnant patches now survive—in forested valleys in this area.*

Rainforest classification

Adapted from Walker and Hopkins (1984)

The structural classification of Australian rainforests is based on a combination of descriptive features. These include predominant leaf sizes of the canopy trees, species composition, the presence of distinctive plant structures (e.g. root buttresses) and the visual dominance of certain growth forms, either on the trees or as an understorey (e.g. mosses, ferns, palms and vines).

The terms used to describe structural complexity and predominant leaf sizes are explained below. Forests may be classed as either 'simple' or 'complex' if they exhibit most or all of the features listed. There is a huge variety of leaf shapes in rainforests and for a given leaf area the lengths vary according to the leaf shape. The length of the most common leaf shape, the 'lanceolate' or elliptical leaf, is given for each size category as an example.

Structure

Simple	*Complex*
Single or few dominant tree species	Many tree species
Few plant structures and growth forms dominant	Wide range of plant structures and growth forms
Uniform tree stem sizes and often distinct lower strata	Uneven stem sizes and no distinguishable lower strata

Leaf size

Leaf size class	*Leaf area* (mm^2)	*Length of lanceolate leaf* (mm)
Mesophyll	>4500	>125
Notophyll	2025–4500	75–125
Microphyll	225–2025	25–75
Nanophyll	25–225	<25

A stand of tall rainforest
Photographed in the 1920s near Danbulla, on the Atherton Tableland, this tall rainforest (far right) is now largely cleared. The person standing among the vines at the base of a giant grey sassafras (Doryphora aromatica) is dwarfed by the immense height of this tree.

Tall open forest

Trees >30 m high; 30–70% foliage cover **T3**

These towering *Eucalyptus* forests, which stand over 30 m tall and reach heights near 100 m in places, are the optimum development of Australia's hardwood forests. They contain some of the most commercially valuable trees and have been utilised for timber production for nearly two centuries. There are few areas within them that remain untouched by logging, yet the tall open forests have retained much of their former grandeur.

Tall open forests presently cover about 50 000 km^2 and exhibit a variety of understoreys, ranging from rainforest and tree-ferns to low trees and tall shrubs. The range of tree densities found within these forests, including areas of tall woodland (**T2**), is generalised within the open forest code. Such variations in the canopy may result from European forest management or from natural successions.

Most vegetation of this structural form is dominated by species of *Eucalyptus* and corresponds to what is often called 'wet sclerophyll forest' (Ashton 1981). It usually occurs in areas with high reliable rainfall of over 1000 mm annually. Tall open forests are found in sheltered areas of mountainous terrain in the south-western corner of WA and from Tas. to northern NSW. Smaller unmapped outliers occur as far north as the Windsor Tableland in northern Qld.

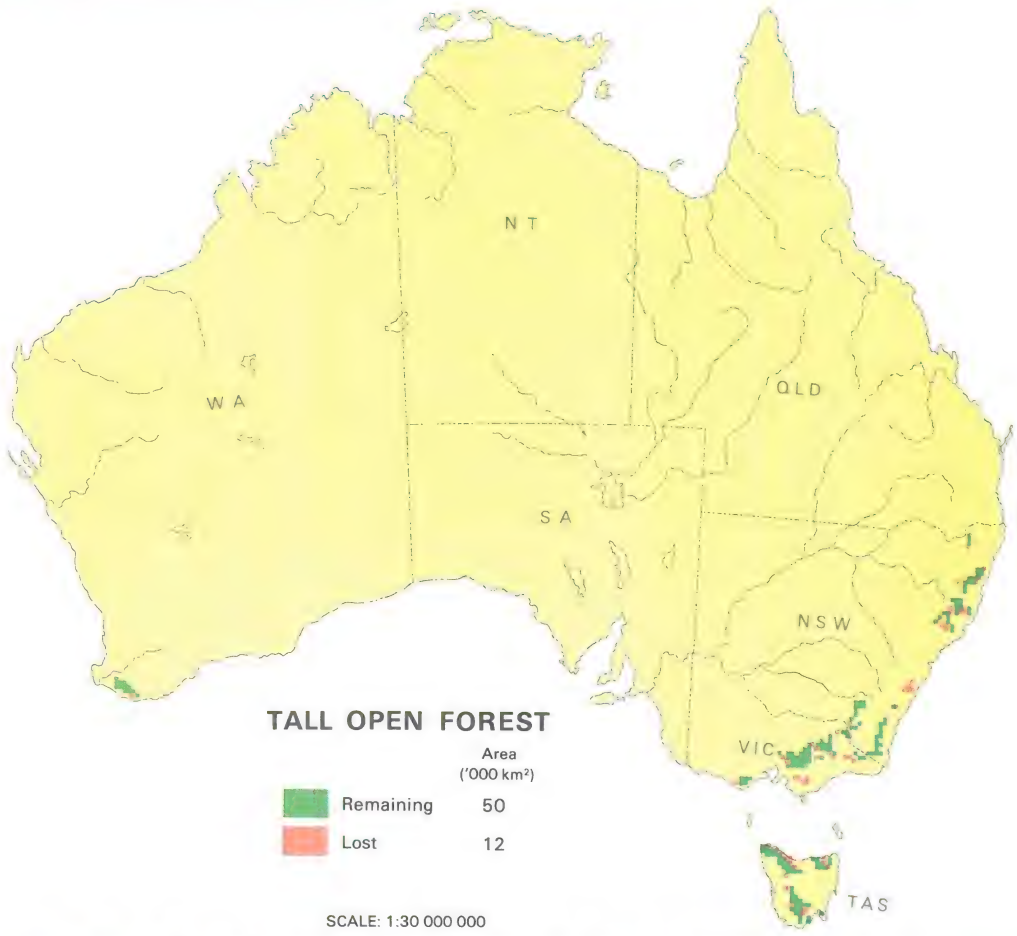
The most important species include *Eucalyptus diversicolor* in WA; *E. regnans* in Tas. and Vic.; *E. delegatensis*, *E. obliqua* and *E. viminalis* in Tas., Vic. and NSW; and *E. pilularis*, *E. saligna*, *E. grandis* and *E. propinqua* in NSW and Qld. Stands of these forests are often even-aged, due to uniform regeneration after occasional massive crown fires.

Most of these forests have a distinctive lower stratum of low trees and tall shrubs (**eT3L**), many of them orthophyllous (soft-leaved). Fire-determined successions within the understoreys have been identified but, in view of the variation in the available evidence (Ashton 1981), the lower strata of the pre-European forests are assumed to have been the same as at present.

In the eastern forests the height of the lower stratum often exceeds 10 m in very moist situations, especially in Vic. and Tas. Tree-ferns are prominent in these forests, along with *Acacia melanoxylon* and the genera *Pomaderris*, *Olearia* and *Bedfordia*. Palms occur in the northern examples, and *Casuarina*, *Syncarpia* and *Callicoma* are common. The understorey in the *E. diversicolor* forests of WA is similar to those in the east, apart from the absence of ferns and the prominence of tall shrubs (**eT3S**).

Rainforest species do occur in the understorey of some eastern forests, though in Tas. there are areas where the lower stratum is a closed forest dominated by *Nothofagus cunninghamii* (**eT3M**). Within parts of these areas in Tas. the cover of the tallest stratum tends to be less than 30% (**eT2M**). These stands represent stages in long-term transitions where the taller relict eucalypts are being replaced by rainforest (Gilbert 1959).

The distribution of the tall open forests is somewhat more extensive on the Natural Vegetation map. Some areas have been cleared for sowing to exotic pastures (**yfF3**, **yfF4**, **eM1yF**) or to induce the growth of native pastures (**eM1yG**).

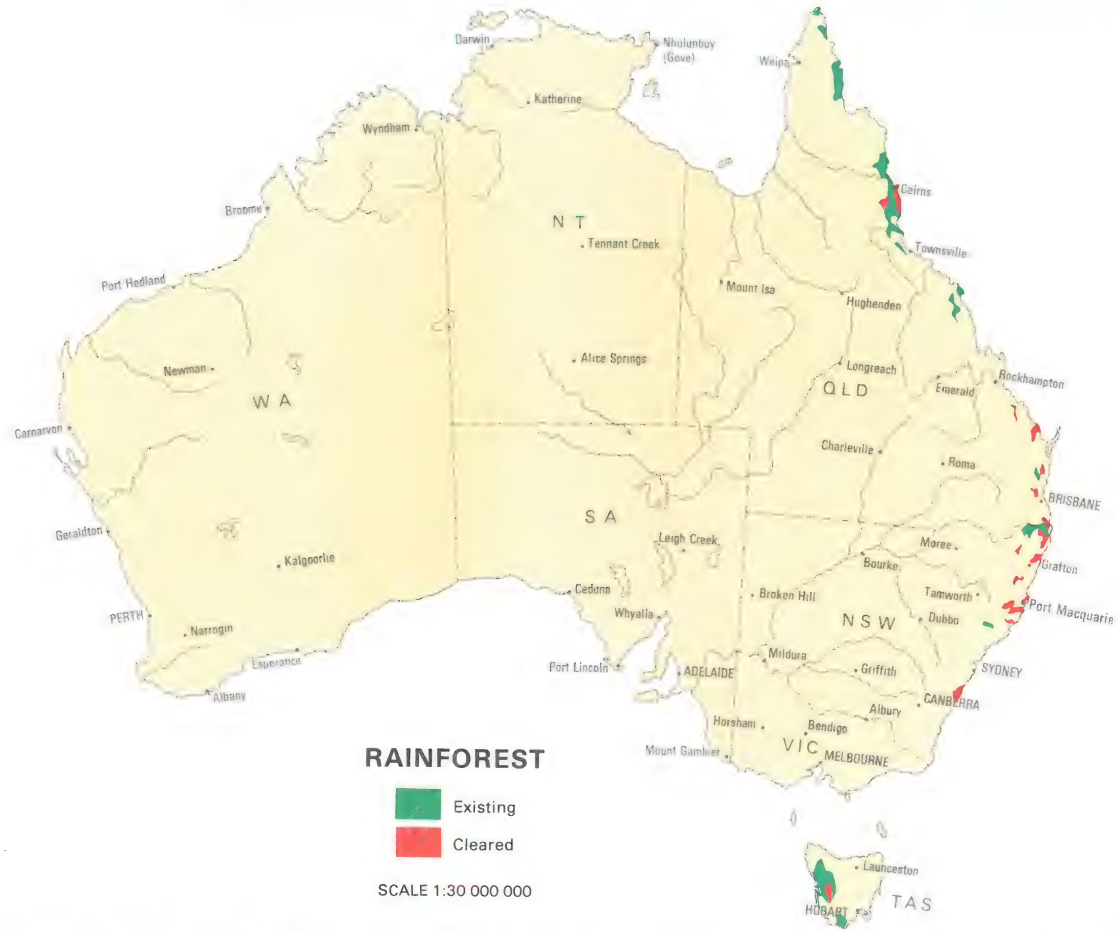


Karri tall open forest
In the high rainfall area of the far south-west of WA, the smooth-barked karri (Eucalyptus diversicolor) *forms tall open forests. An understorey dominated by dense tall shrubs is a dinstinctive feature of many karri forests. As a result they have been generalised as* **eT3S** *on the 1:5 million scale maps.*

Mountain ash forest
Looking up into the canopy of a mountain ash (Eucalyptus regnans) *tall open forest in Vic. (far left). Mountain ash forests typically stand over 30 m tall. Australia can boast the tallest flowering plants in the world, with some individuals of this species standing nearly 100 m high in moist protected sites in Tas.*

Medium trees

Closed forest — Trees 10–30 m high; >70% foliage cover — M4



Southern beech rainforests
The genus Nothofagus *is confined to the southern hemisphere. In Australia, two major species dominate the cool temperate rainforests. The negrohead beech* (N. moorei) *is restricted to small areas in the highlands of northern NSW (pictured above) and south-eastern Qld, while the myrtle beech* (N. cunninghamii), *right, is widespread in Tas. and also occurs in eastern Vic. Another species, the deciduous* N. gunnii, *occurs in low closed forests in highland parts of Tas.* Nothofagus *forests are structurally simple; they often have a single dominant species and contain few specialised growth forms other than ferns and mosses.*

Most of the native closed forests fall into the category loosely known as 'rainforest', which covers a diverse range of types from the cool temperate southern beech forests in Tas. to the tropical vine forests of Cape York. Small rainforest patches also occur in the Top End of the NT and in the Kimberley region of WA. The closed forest category also includes some planted forests of introduced pines.

Rainforests presently cover around 20 000 km^2. While it is difficult to determine their total former extent, it is clear that a large part of the original rainforest has been lost. However, the future of Australia's remaining rainforest now seems secure, with large sections conserved in national parks and other reserves and, more recently, within World Heritage Areas.

Rainforest distribution is indicated in part by the bounded areas on both 1:5 million scale maps, but it is amplified by the symbols used to represent smaller patches. It should be noted that these symbols are limited to stands covering more than 500 ha, and to vegetation over 10 m in height; isolated symbols usually represent agglomerations of smaller patches in the same general area.

Most rainforests occur in areas of high rainfall (>1200 mm annually) which ranges in different places from fairly uniform to markedly seasonal. In addition, they are found from sea level up to altitudes of more than 1200 m and on a wide range of soil types. Their environmental relationships are complex, as reflected in their classification (Webb 1959, 1968; Webb and Tracey 1981) which has had to be greatly generalised for the maps.

There are four broad climatic groupings of Australian rainforest. Tropical rainforest occurs in north Qld, subtropical and warm temperate types from Mackay (Qld) to east Gippsland (Vic.), and cool temperate rainforest in Tas. and Vic. These groupings correspond respectively to Webb's 'mesophyll vine forest', 'notophyll vine forest', 'microphyll fern forest' and 'nanophyll moss forest'.

Most of the rainforest trees are evergreen, although there are some deciduous species. Most are also orthophyllous, but again there are exceptions. The mesophyll vine forests typically consist of large numbers of species and have a complex structure of mixed tree heights with various specialised growth forms. Many of the notophyll vine forests exhibit similar characters, being distinguished mainly by the smaller leaves.

Because of their complexity, all mesophyll and notophyll rainforests are mapped simply as **xM4** without reference to subforms. There is a reduction in floristic diversity and structural complexity in the transition from notophyll vine forest to microphyll fern forest. The nanophyll moss forests can consist of little more than a fairly uniform tree stratum, and are often dominated by a single species—*Nothofagus cunninghamii* (**nM4**).

There are many variations of this pattern, resulting from seasonal drought, increasing altitude and decreasing soil fertility. For example, another species of *Nothofagus*, the larger leaved *N. moorei*, dominates some closed forests at higher altitudes in north-eastern NSW, with outliers in south-eastern Qld. One such area is mapped (**nM4**) on the Barrington Tops, north of Newcastle (NSW).

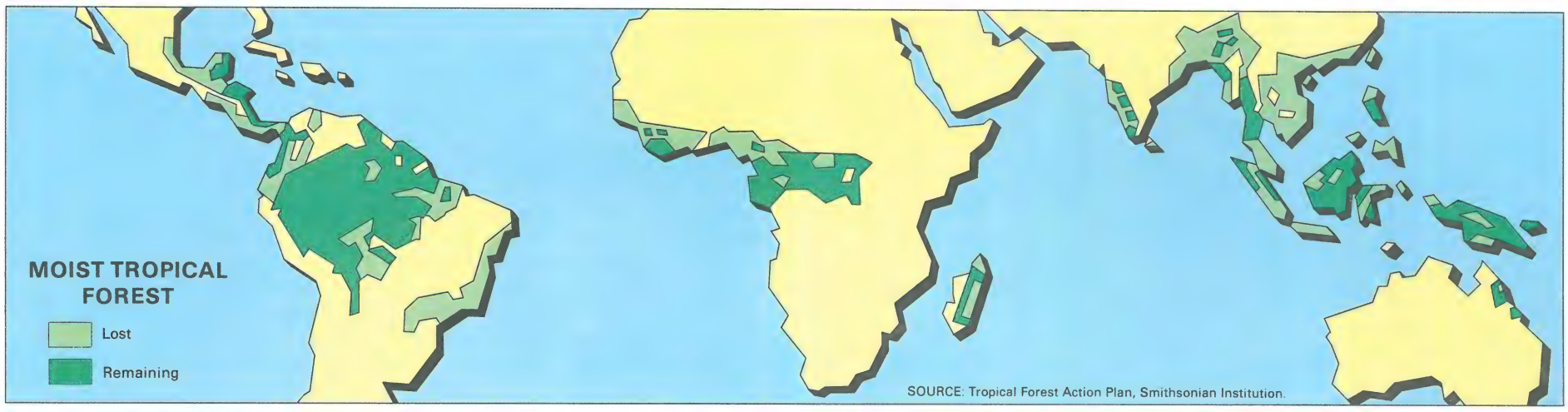
The classification of closed forests is further complicated by the occurrence of emergents above the general forest canopy. In particular, there is a tendency for species of *Araucaria* to occur as emergents above some closed forests in Qld and northern NSW (Webb 1959) and for species of *Eucalyptus* to do the same in Tas. Such stands may be regarded as stages in long-term transitions, the taller stratum being the relict element.

Rainforests are more extensive on the Natural Vegetation map. Some areas have been cleared for sowing to exotic pastures (**yfF4**, **eM1yF**), to induce the growth of native pastures (**yG3**, **eM1yG**) or for the establishment of plantations of sugar cane (**vG4**). The presence of remnant eucalypts in some cleared units reflects the mosaic nature of the areas generalised as rainforest. A large area of open scrub (**xS3G**) in western Tas. appears to be the product of a series of fires in former *Nothofagus* rainforest (Kirkpatrick 1977).

Rainforests also occur on several Australian islands beyond the limits of the maps. These are Lord Howe Island, where the forests are largely preserved; Norfolk Island, where the forests have mostly been cleared and sown to exotic pastures; and Christmas Island (Indian Ocean), where the forests have been subject to clearing for phosphate mining.

The Present Vegetation map includes a special category of closed forest, namely the plantations of exotic pine trees (**pM4**) in south-eastern and south-western Australia. *Pinus radiata* is the principal species planted in the southern states, with *P. pinaster* also common in WA. Although there is a large number of pine plantations, only a few areas are large enough to be represented on the map.

M4



Original and present extent of the world's moist tropical forests
Tropical rainforests represent most of the world's broadleaved closed forests. Only the largest existing areas of wet tropical rainforest are shown, along with an estimate of its extent prior to human clearing. In Australia the term 'rainforest' includes the native temperate closed forests.

What is a rainforest?

The popular conception of a dim and damp jungle where little light filters through a high canopy to the mosses, ferns and leaf litter below serves as a useful identifier of rainforest. A definition which encompasses the diversity of specific regional types of Australian rainforest is difficult to obtain, but in structural terms it is a dense formation of diverse tree types, floristically distinct from the surrounding *Eucalyptus* forests. Rainforests are distinguished from other closed forests by the presence of growth forms such as epiphytes, lianes, mosses and ferns. Of course, there are many transitional types and mixtures of sclerophyll forest and rainforest species.

Why conserve rainforest?

Although Australia's rainforests are only a small fraction of the world total, they have evolved in relative isolation for many millions of years and are therefore unique. They have been described as a cradle of flowering plant evolution and constitute limited habitats where large numbers of primitive organisms have survived.

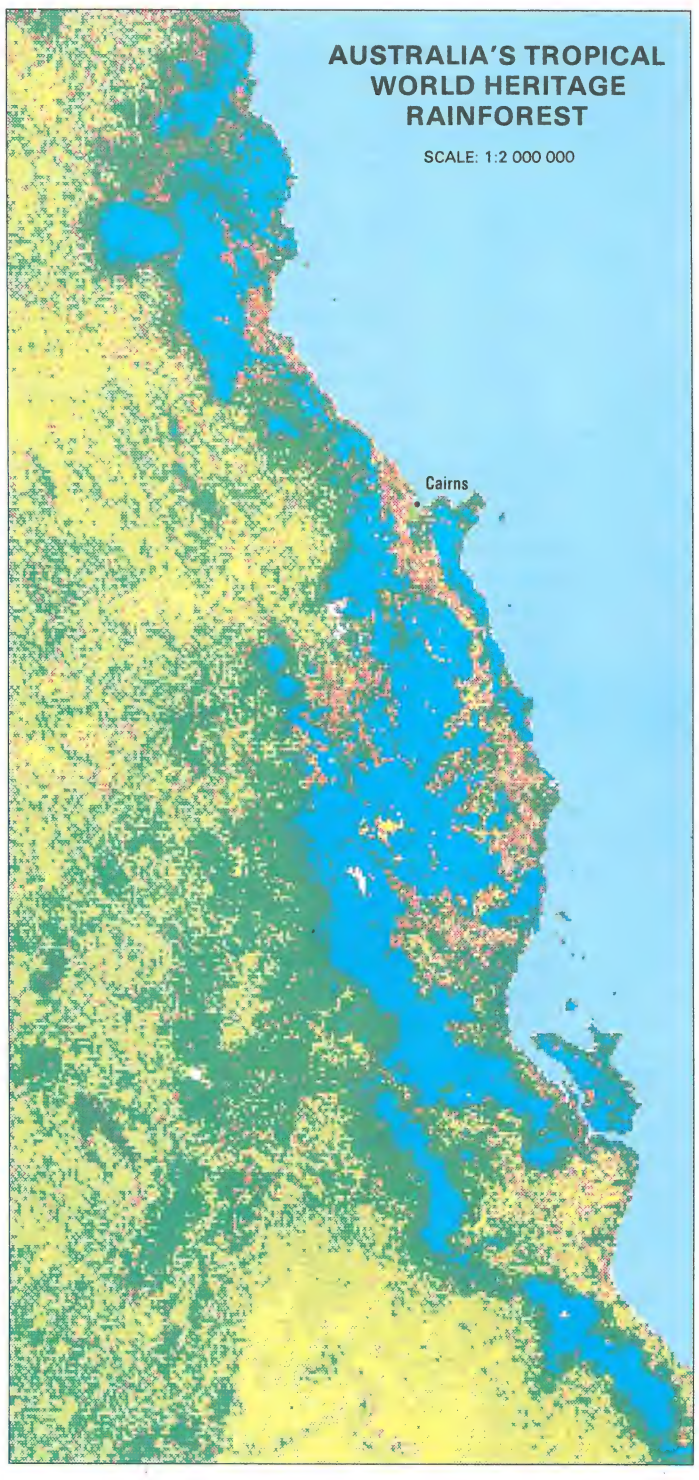
Rainforests are reservoirs of genetic diversity providing material benefits such as medicines and foods. They also offer a unique recreational experience for both present and future generations. Rainforests are an integral part of the global ecosystem on which human life depends. Worldwide, they are being cleared at an alarming rate.

The largest tracts of rainforest in Australia extend from Cooktown to Ingham in northern Qld and in total they cover over 6500 km^2. The extent of rainforest vegetation in this region is highlighted on the map (right), produced digitally from a mosaic of five Landsat satellite images.

Areas of rainforest are coloured blue. The surrounding *Eucalyptus* open forest and woodland are shown green and the open woodland and grassland further inland are yellow. Cleared agricultural land appears orange-red.

There are various structural types of rainforest in this area, ranging from the complex mesophyll vine forest of the lowlands to the simple microphyll vine-fern forests of the cloudy wet highlands. The most widespread type is mesophyll vine forest which covers over 2000 km^2 (Rainforest Conservation Society of Qld 1986).

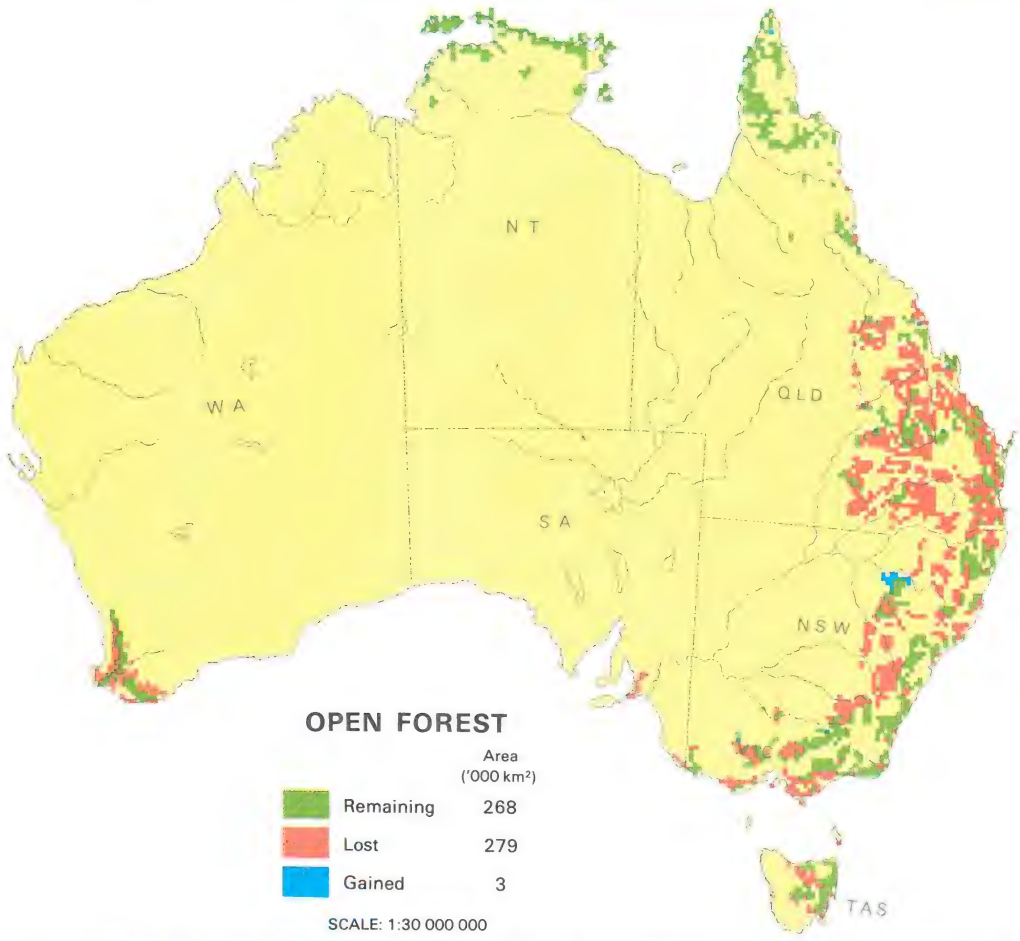
In 1989 most of the wet tropical rainforests in this region were included in the successful nomination of an area of World Heritage by the Commonwealth in an effort to secure their protection from further development.



Northern Qld rainforests
Upland microphyll vine-fern forest (above), clothed in mist, among the granite boulders on Thornton Peak (altitude 1400 m), north of the Daintree River. Inside the jungle of a mesophyll vine forest (left) near Cape Tribulation. These examples represent the diversity of rainforest types in northern Qld and include differences in leaf sizes, growth forms and structural complexity, and types with deciduous elements or emergents.

Open forest

Trees 10–30 m high; 30–70% foliage cover **M3**



Open forests form the bulk of Australia's forested country and are the primary source for the nation's timber industry. Native open forests, with *Eucalyptus* hardwoods predominant, cover 3.5% of the continent, only about half of their original extent.

Roughly half of the existing 140 000 km^2 of open forests lie within state forests, with a further 50 000 km^2 set aside in national parks and other reserves. Large areas of state forest are harvested on a regular production cycle so that at any time different parts are at various stages of regeneration.

Open forests are generally confined to the coasts and nearby ranges though *Acacia* forests extend well inland in Qld. They exhibit a variety of subforms, with understoreys ranging from low trees and shrubs to tussock grasses or, in some cases, mostly bare ground.

Eucalypt open forest over low trees
Many Eucalyptus *open forests of the coasts and ranges in south-eastern Australia have an understorey made up of low trees and tall shrubs* (**eM3L**). Acacia, Casuarina *and* Banksia *are common in the lower tree layer, as are saplings of the canopy trees. In the ground layer, grasses and bracken fern are common. The understoreys are often a variable mosaic depending on their fire history. The photo shows a stand of southern mahogany* (Eucalyptus botryoides) *over low trees of* Banksia serrata *and* Acacia *shrubs.*

Open forest with low trees and tall shrubs — M3L–M3S

Eucalyptus is the most widespread floristic type but, as indicated on the Natural Vegetation map, *Acacia* and *Casuarina* were once of regional importance. *Eucalyptus* forests (**eM3L**, **eM3S**) occur in coastal and upland areas in the south-western corner of WA; from Tas. to central Qld in the east; on Cape York Peninsula; and also in the Top End of the NT.

South of the Tropic these forests occur under lower rainfalls or on poorer soils than the tall open forests. They are smaller in stature and have a more open understorey of sclerophyllous low trees and tall shrubs, which include *Acacia*, *Banksia* and *Casuarina*. The large number of dominant species includes *Eucalyptus marginata* and *E. calophylla* in WA; *E. viminalis* and *E. obliqua* from Tas. to NSW; *E. radiata* and *E. sieberi* in Vic. and NSW; and *E. maculata*, *E. gummifera* and *E. crebra* in NSW and Qld.

In northern Qld and the NT the dominant *Eucalyptus* species include *E. tetrodonta* and *E. miniata*. While these forests have some features in common with those further south, the woody understorey includes orthophyllous elements, such as *Terminalia* and *Buchanania*. Palms (e.g. *Livistona*) and cycads (e.g. *Cycas*) are also prominent in some areas, and there is a seasonally dense cover of tropical grasses. *Callitris intratropica* is present in some areas and is mapped as a co-dominant south of Cape Cockburn in the NT (**epM3L**).

The distribution of the northern forests is little changed except for some clearing near Darwin (**eM1yG**) and Cairns (**vG4**). But in the southern forests about half the original area has been cleared or thinned for native (**yG3**, **eM1yG**) or sown exotic pastures (**yfF3**, **yfF4**, **eM1yF**). Coniferous plantations (**pM3**, **pM4**), seasonal crops and horticulture have also replaced some forests. Timber removal practices, burning, and grazing by cattle have modified both the tree density and the understorey in some remaining forests. Large sections of *Eucalyptus marginata* forest, the jarrah of south-western WA, have been degraded to woodland (**eM2Z**) by the 'dieback' fungus *Phytophthora cinnamomi*.

Only limited areas of *Acacia* forests of this subform (**wM3L**) appear on the Present Vegetation map. These are the relics of forests that occupied large areas of fertile heavy soils in eastern Qld, with outliers in northern NSW. Their distribution overlapped with that of the inland *Eucalyptus* forests, but extended further west into areas with annual rainfall below 500 mm. The principal species was *Acacia harpophylla*, though *Casuarina cristata* was often co-dominant (**cwM3L**, **wcM3L**) or even dominant (**cM3L**) on some soils. *Eucalyptus populnea* was also common in the more mixed forests. A wide range of low trees and tall shrubs, most frequently *Eremophila mitchellii* and *Geijera parviflora*, formed a variable understorey (Isbell 1962, Johnson 1964).

Most of the former forests of *Acacia* and *Casuarina* have been cleared to induce native pasture growth. In many cases the remaining tree layer contains only relics of the previously sub-dominant *Eucalyptus* species (e.g. **eM1yG**). Partly because *Acacia harpophylla* tends to regenerate in the native pastures, large areas in Qld (from near Clermont in the north to Goondiwindi in the south) have been further modified and sown to pastures of exotic grasses (**yG3**, **yF4**), or to seasonal crops on the better soils.

Open forest with low shrubs — M3Z

Eucalyptus is by far the most frequent dominant of these forests (**eM3Z**). The lower stratum is often dense and the shrubs are typically sclerophyllous, hence the term 'dry sclerophyll forest'. In south-eastern Australia these forests are generally found on less fertile soils or under lower annual rainfalls (to less than 600 mm) than the previous *Eucalyptus* types (**eM3L**, **eM3S**).

M3

The more widespread dominant species include *Eucalyptus baxteri* and *E. obliqua* in SA and Vic.; *E. macrorhyncha* and *E. sideroxylon* in Vic. and NSW; *E. crebra* and *E. gummifera* in NSW; and *E. intermedia* and *E. acmenoides* in south-eastern Qld. Similar forests on the tip of Cape York Peninsula are dominated by *E. tetrodonta* and *E. nesophila*.

The natural extent of these forests in the south-east has been reduced under European land uses. To encourage native pastures, some areas have been modified by partial timber removal, burning and grazing. Other areas have been cleared for exotic pastures (**yfF3**, **yfF4**, **eM1yfF**) and seasonal crops, or for pine plantations (**pM4**). Some forests shown as **eM3Z** on the Present Vegetation map are kept in this condition by frequent burning of any taller understorey. Conversely, a remnant area near Adelaide has been invaded by tall exotic shrubs following disturbance and is now mapped as **eM3S**.

Shrubby open forest
Scribbly gum (Eucalyptus signata) *and pink bloodwood* (E. intermedia) *are the dominant species in this stand* (**eM3Z**) *near Beerwah (Qld). The term 'dry sclerophyll forest' is often used to describe* Eucalyptus *open forest with a sclerophyllous low shrub understorey.*

Open forest with tussock grasses and graminoids — M3G

Eucalyptus forests with a grassy understorey (**eM3G**) are prominent in the present vegetation of eastern Qld and north-eastern NSW. The characteristic species include *Eucalyptus drepanophylla*, *E. intermedia* and *E. tereticornis*, with *Themeda australis*, *Imperata cylindrica* and species of *Heteropogon* as the major grasses. In some cases the grassy rather than shrubby understorey is related to the presence of heavy soils, while in others it may have been due initially to regular burning by Aborigines. More recently, European forest management and grazing have led to the extension of grass understoreys in areas shown as **eM3L** on the Natural Vegetation map.

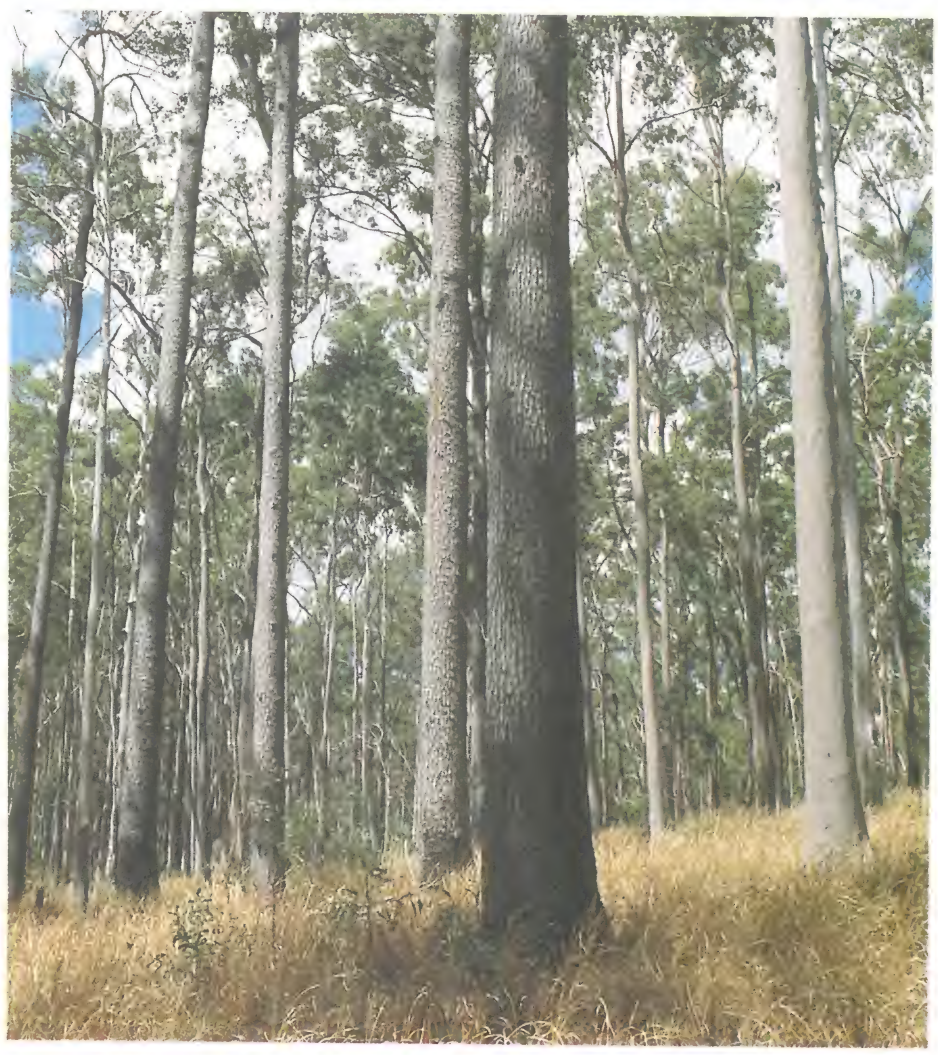
Some of the natural grassy forests (**eM3G**) in eastern Australia have been cleared or thinned (**eM2G**, **eM1yG**, **yG3**) to increase the grazing value of the native grasses. Others have been replaced by plantations of sugar cane (**vG4**), or by exotic sown grasses and legumes (**yfF4**, **yG3**, **yG4**) with some crops.

Some of the *Eucalyptus tetrodonta–E. miniata* open forests in the Top End of the NT have only a sparse woody understorey and are therefore mapped as **eM3G**. The grasses in these areas include *Plectrachne pungens* and annual species of Sorghum.

In central Tas. a variable forest dominated by *Eucalyptus delegatensis*, with a grassy understorey including species of *Poa*, appears to show the results of clearing, burning and grazing.

Narrow fringing woodlands of *Eucalyptus camaldulensis* are widespread along the rivers of inland Australia. However, on the floodplains of the Murray River *E. camaldulensis* forms broad forest stands with a lower stratum of tussocky or tufted grasses and graminoids (**eM3G**).

Forests dominated by species of *Melaleuca* (**mM3G**) have a patchy distribution in low-lying coastal areas of Qld and the NT though the only areas now mappable are near Darwin, where *M. leucadendra* is a characteristic species. There are both grasses and graminoids in the herbaceous stratum. A former stand of similar vegetation south of Brisbane, dominated by *M. quinquenervia*, has been replaced by sown exotic pasture (**yfF4**).



Grassy open forest near Gympie (Qld)
The largest natural areas of this forest type (**eM3G**) *occur in eastern Qld, extending from inland of Brisbane along the coast to near Cooktown. The area of grassy forests has increased in south-eastern Australia with the modification by burning and grazing of other open forest types.*

Open forest with no significant lower stratum — M3

The Present Vegetation map shows some areas along the Qld coast near Brisbane coded as **pM3** which replace former *Eucalyptus* forest (**eM3L**). These are plantations of the exotic *Pinus elliottii*, which have a more open canopy than those of *P. radiata* (**pM4**). Unmapped smaller coniferous plantations in the same region also include the native *Araucaria cunninghamii*.

The inland areas coded **pM3** in eastern Australia represent forests of *Callitris glaucophylla*. Stands of this native conifer typically have very sparse understoreys. According to Rolls (1981), the present-day 'Pilliga Scrub' in northern NSW appears to have developed from dense regrowth in historical times from a more open, mixed woodland (**peM2G**). The areas mapped in central Qld may have been reduced by disturbance. The sensitivity of *Callitris* to fire is a contributing factor in the historical changes to these forests.

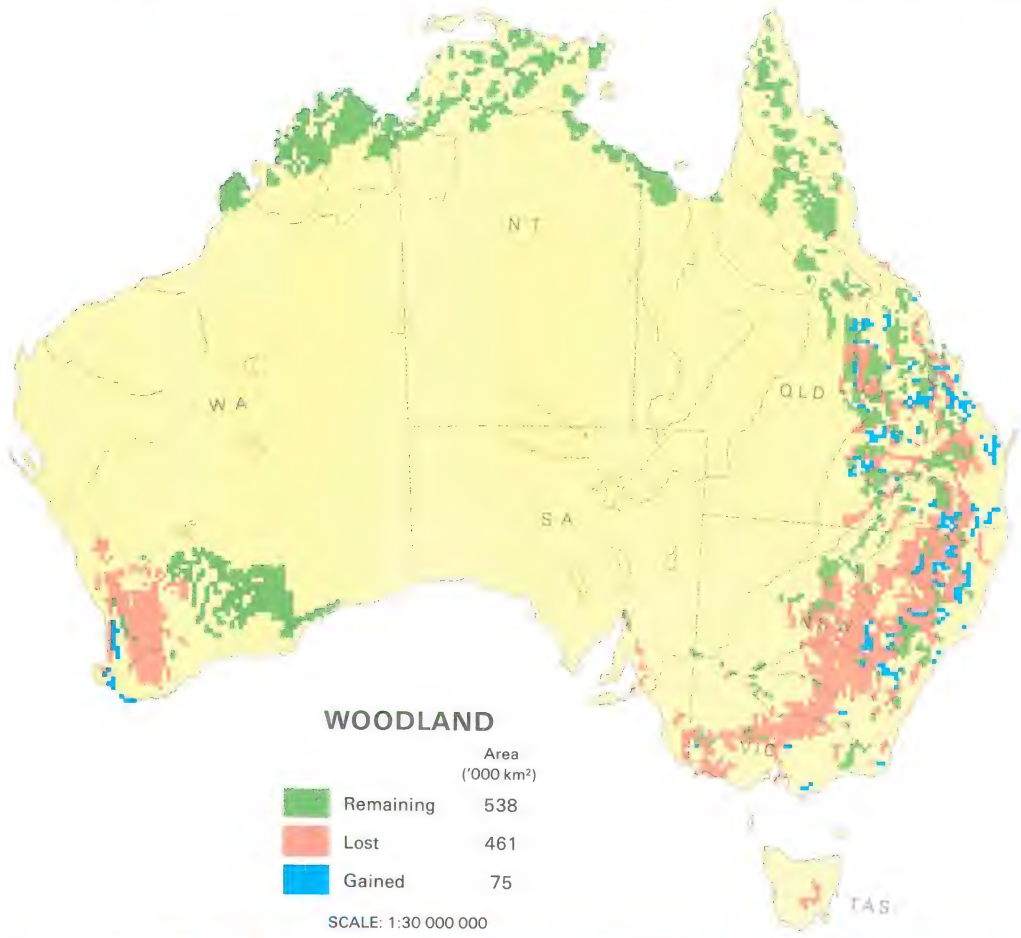
The present areas of **wM3** east of St George and **weM3** north of Morven in southern inland Qld are dominated by *Acacia catenulata*, with some admixture of *Eucalyptus* species. The other areas of **wM3** are relics of a much larger area of *Acacia aneura* forest, often accompanied by *Eucalyptus populnea* or *E. melanophloia* (**weM3**). Grasses and low shrubs may be present but are typically very sparse. *A. aneura* forest is found on distinctive red earth soils in areas with as little as 400 mm annual rainfall. Much of it has been cleared or thinned (e.g. to **weM1yG**) to induce a better growth of native grasses.

Mulga open forest in inland Qld
There is a marked absence of any understorey or ground cover in this dense mulga (Acacia aneura) *forest* (**wM3**). *These open forests, with up to 1200 trees per ha and foliage cover of 30–40%, represent the optimium development of this species. The mulga open forests, often mixed with poplar box, formerly extended over a large area between Charleville and St George, but many have now been cleared to develop pasture for livestock grazing.*

Woodland

Trees 10–30 m high; 10–30% foliage cover

M2



Woodlands form a transitional zone between the higher rainfall forested margins of the continent and the arid interior. *Eucalyptus* is the most widespread tree component, though there is a wide range of understorey types.

Woodlands have been almost entirely removed from the cereal cropping lands in the south-east and the far south-west of Australia. Pasture improvement and tree thinning have been extensively employed within the grassy woodlands, while the shrubby understorey of others has been removed to increase pasture growth.

Woodland with low trees and tall shrubs

M2L–M2S

These 'layered woodlands' (**eM2L**, **eM2S**) are widespread in the coastal regions of northern Australia and are also found further inland in eastern Australia. They formerly occurred in the south-west of WA but today there are only a few scattered remnants.

Some of these woodlands can be regarded as extensions of adjacent *Eucalyptus* forests into less favourable environments, where they are both structurally and floristically similar. In general, these woodlands occur where annual rainfall is lower (down to <400 mm in temperate Australia), though in some cases the relative distribution of forests and woodlands is also related to soil factors.

The lower stratum is marked by its floristic diversity and in places by its high density. *Acacia*, *Callitris* and *Casuarina* are prominent in the lower stratum in some areas, and indeed may be taller and co-dominant with *Eucalyptus* (e.g. **ewM2L**, **peM2S**), especially in southern Qld and northern NSW. *Melaleuca* dominates the understorey of some northern units; others contain numerous genera including *Terminalia*, *Erythrophleum* and *Planchonia*. While the ground layers in general are herbaceous, some northern examples are distinguished by the presence of hummock grasses.

Across northern Australia the characteristic woodland trees include *Eucalyptus dichromophloia*, *E. miniata*, *E. tetrodonta* and *E. polycarpa*. Other major species include *E. crebra*, *E. populnea* and *E. melanophloia* in Qld and NSW; *E. microcarpa* (*E. woollsiana*) in NSW; *E. ovata* and *E. sieberi* in Vic.; and *E. loxophleba* and *E. gomphocephala* in south-western WA.

The distribution of the northern woodlands is unchanged except where they have been replaced by sugar cane (**vG4**) in the Ayr district, near Townsville. However, the present distribution of the eastern and southern woodlands is much reduced from their natural extent. In better watered areas these woodlands have been cleared for pasture and cereal crops. Others have been cleared or thinned to increase the growth of native grasses. Horticulture has replaced woodland in some places.

Some areas shown as **eM2L** or **eM2S** on the Present Vegetation map represent the results of the modification of open forests, for example the partly cleared ranges running south from Dubbo in central NSW.

Layered woodland of grey box and cypress pine
Woodlands having a low tree and tall shrub understorey, the 'layered woodlands', are related to and often as dense as the drier forests. This photo of a remnant patch of natural layered woodland (**eM2L**)*, near Coolamon (NSW), shows grey box* (Eucalyptus microcarpa) *over white cypress pine* (Callitris glaucophylla)*. This vegetation type was formerly widespread over the area now occupied by the wheatbelt in NSW.*

Darwin stringybark woodland with mixed understorey of low trees
This species (Eucalyptus tetrodonta) *dominates woodlands and open forests right across the wetter parts of northern Australia. In the Top End of the NT it is commonly associated with Darwin woollybutt* (E. miniata) *in woodlands with a distinct understorey layer of low trees* (**eM2L**)*. In this stand, south of Darwin, there is a variety of low trees including* Acacia, Planchonia *and* Terminalia*. Livistona palms, seen here in the foreground, are also a feature of this vegetation type.*

Woodland with low shrubs

M2Z

Again, some of these woodlands (**eM2Z**) are extensions of adjacent 'dry sclerophyll forests' but others are quite distinct. The main occurrences are in the south-east and south-west, with one isolated example near Cape York. The numerous dominant species include *Eucalyptus tetrodonta* in northern Qld; *E. sieberi*, *E. macrorhyncha* and *E. sideroxylon* in NSW and Vic.; *E. leucoxylon* in SA and Vic.; and *E. wandoo* and *E. salmonophloia* in WA. Woodlands dominated by *E. salmonophloia* occur in areas where the annual rainfall ranges down to 200 mm.

The low shrub layer is typically sclerophyllous but semi-succulent Chenopodiaceae, including *Atriplex* and *Maireana*, are dominant on the alkaline soils that are widespread in the lower rainfall woodland areas of WA. Chenopods also form the shrub understorey of the *Eucalyptus largiflorens* and *E. camaldulensis* woodlands (**eM2Z**) on some floodplains of the Murrumbidgee River system.

The natural distribution of woodland with low shrubs has been much reduced, especially in south-western WA. Here, a large proportion, which included some *E. loxophleba* woodland (**eM2S**), has been cleared and sown to seasonal pastures (***yfF3***, ***yfF4***) and crops.

Some areas of **eM2Z** represent modifications to former open forests, including the notable example of dieback of *E. marginata* forest in WA. The areas mapped as **peM2Z** and **epM2Z** in the present vegetation of northern NSW are probably remnants of more dense former woodlands.

M2

Woodland with hummock grasses M2H

This woodland type (**eM2H**) is mapped only in central Qld. The tallest stratum is dominated by *Eucalyptus similis*, which tends to occur in groves, and the characteristic hummock grass is *Triodia mitchellii*.

Patches of similar vegetation occur within the grassy *Eucalyptus* woodlands (**eM2G**) in the Kimberley region of WA and the Top End of the NT. *Plectrachne pungens* is frequent in the ground layer of many of these woodlands and, although it tends to occur in the tussock form where tussock grasses are dominant, it becomes a dominant hummock grass under lower rainfalls and on poorer soils.

Woodland with tussock grasses M2G

Eucalyptus woodlands of this subform (**eM2G**) occur in many places in the better watered parts of northern and eastern Australia, from the Kimberley region of WA to south-eastern SA. Within the broad areas mapped as grassy woodland, however, there may be localised variations in both tree height and density. In the broken sandstone country of the Kimberley region, for example, there are many poorer sites which carry only sparse low open woodland vegetation.

The grassy woodlands tend to be associated with heavier or more fertile soils than those with a shrubby or hummock grass understorey; large areas have therefore proved favourable for agriculture. Besides the mapped areas, grassy woodlands also occur on alluvial flats along rivers throughout much of the country.

The wide distribution of grassy woodlands is reflected by the numerous dominant species, as can be seen on the map of *Eucalyptus* species groups on page 14. Again, *Eucalyptus tetrodonta* and *E. dichromophloia* are widespread across northern Australia, with *E. miniata* common in the NT and *E. polycarpa* in Qld.

Eucalyptus crebra, *E. populnea* and *E. melanophloia* are prominent west of the coastal ranges in Qld and NSW, with *E. tereticornis* more common in coastal valleys. *E. albens* and *E. melliodora* favour the inland side of the ranges in NSW and Vic., with *E. microcarpa* on the plains further west. *E. viminalis* is common on the ranges from NSW to SA and in Tas. *E. leucoxylon* and *E. camaldulensis* are major species in SA and western Vic.

Species of *Callitris* and *Acacia* are co-dominant with *Eucalyptus* in some places (**epM2G**, **ewM2G**), or even dominant as in the case of a small area of *Callitris* near Goondiwindi in Qld (**pM2G**).

Some grassy woodlands in monsoonal northern Australia contain some of the few deciduous species of *Eucalyptus*, including *E. alba*, *E. grandifolia* and *E. latifolia*.

Eucalyptus camaldulensis occurs on plains and even some hill slopes in western Vic. and south-eastern SA. It is also common along rivers in many parts of the country and, with *E. largiflorens*, is dominant along the Murray and Murrumbidgee rivers.

There are many tussock grass species in the woodlands. Prominent grasses include species of *Sorghum* (annual and perennial), *Heteropogon* and *Chrysopogon* across northern Australia; *Bothriochloa* and *Aristida* from tropical northern Australia to NSW; and of *Poa*, *Danthonia* and *Stipa* in the south-east including Tas. *Themeda australis* occurs in all of these areas.

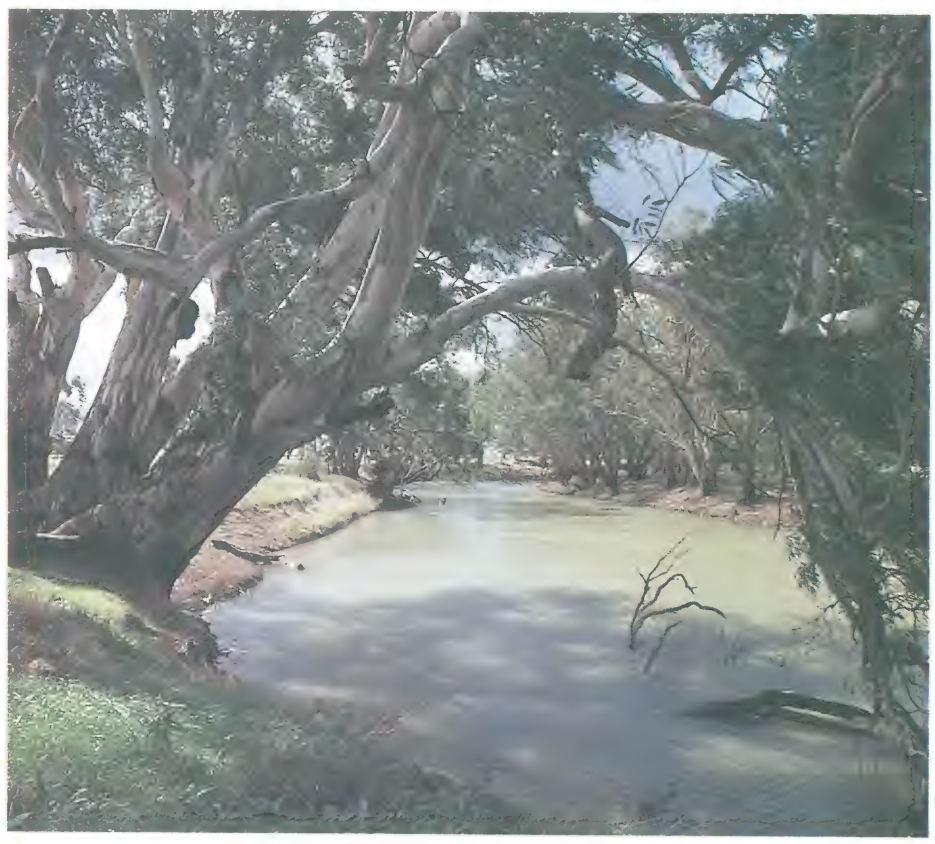
The distribution of the northern grassy woodlands is largely unchanged, except for a small area of regrowth on formerly cleared land south of Darwin (**xS1yG**), and one of grasses and summer crops in the Mareeba district near Cairns (**yG3**). Many of these woodlands are grazed by cattle, usually on grasses that are fired annually. This combination of burning and grazing appears to have led to floristic changes among the grasses, including a decline in *Themeda australis* and an increase in the less desirable *Heteropogon contortus* (Isbell 1969).

In contrast, most of the eastern and southern grassy woodlands have been extensively changed, either through clearing for pastures and seasonal crops or thinning to increase native grass growth (**eM1yG**). In some places the partial removal of timber has been followed by many deaths among the remaining trees.

Some present stands of vegetation shown as **M2G** are the result of changes to former open forests or shrubby woodlands. Some woodlands along the Murray and Murrumbidgee rivers that are shown as **eM2G** on both maps may formerly have had an understorey of low shrubs, notably Chenopodiaceae.

An area of patchy *Melaleuca* open forest in the Arafura Swamp of north-eastern Arnhem Land is generalised as woodland (**mM2G**). The ground cover throughout consists of grasses and sedges of such genera as *Oryza and Eleocharis*.

Wandoo woodland over low shrubs in the Darling Range (WA)
Wandoo (Eucalyptus wandoo) *is a large crowned tree of up to 25 m in height, occurring on gravelly soils inland from the Darling Range. Xanthorrhoea stands out among other low shrubs in the sclerophyllous understorey* (**eM2Z**). *Associated eucalypts are jarrah, marri and, further inland, York gum. Parts of the original wandoo woodland and open forest have been cleared for agriculture.*

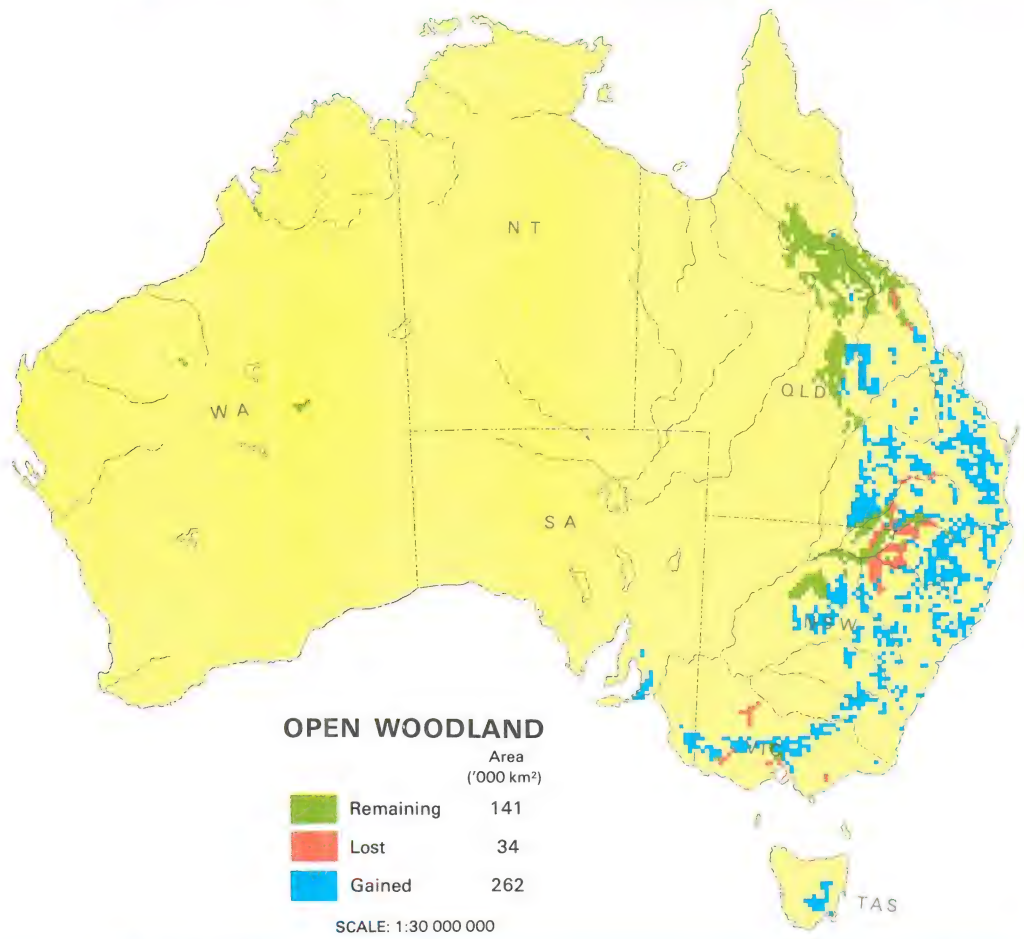


River red gum fringing woodland on the Lachlan River (NSW)
Eucalyptus camaldulensis *is the most widespread of all eucalypts, occurring along almost all seasonal watercourses throughout inland Australia. It is the principal tree along the Murray River and its tributaries, where it forms ribbon-like woodlands and open forests on the floodplains. Many areas have a tussock grass ground cover* (**eM2G**), *but introduced forbs are also common.*

Grassy woodland of Poplar box
One of the most widespread trees of inland eastern Australia is the poplar box (Eucalyptus populnea). *This species occurs in a variety of woodland types, including those with low tree, shrub or tussock grass understoreys. Its main range extends from Narrandera (NSW), north to near Mackay (Qld) and as far inland as Quilpie and Barcaldine in central Qld. Poplar box is frequently co-dominant with cypress pine, mulga or other eucalypts. Grassy poplar box woodland* (**eM2G**), *such as this example from north of Emerald (Qld), is found mostly on alluvial plains in the northern and eastern parts of its range.*

Open woodland

Trees 10–30 m high; <10% foliage cover **M1**



The largest natural occurrences of open woodland are the eucalypt-studded grasslands on the floodplains of the upper tributaries of the Darling River and on the undulating country extending inland from Townsville. Large-scale tree clearing in the agricultural areas of eastern Australia has resulted in the creation of extensive artificial open woodlands.

Open woodlands have lower strata that range from dense low trees to grasses and other herbaceous plants. Open woodlands with a low tree or tall shrub understorey, the layered open woodlands, are a distinct subform related to denser tree formations. The grassy open woodlands are important grazing country. Many former open forests and woodlands have been thinned to encourage the growth of ground layer grasses, or partly cleared for cropping. The remaining scattered trees form open woodlands. Small areas of natural open woodland also occur on grassy alluvial plains throughout the country.

Open woodland with low trees and tall shrubs M1L–M1S

There are several mapped examples (**eM1wL**, **eM1wpL**, **eM1xL**, **epM1xS**) in Qld and NSW along the inland margins of the natural extent of the related layered woodlands (**eM2L**). Some are naturally occurring but others result from clearing within former open forests or layered woodlands.

Eucalyptus populnea is widespread in the upper stratum, with *E. intertexta* more prominent in NSW and *E. melanophloia* in the northernmost areas in Qld. A wide range of genera occurs in the lower woody stratum. Species of *Acacia*, especially *A. aneura* in the south and *A. cambagei*, *A. coriacea* and *A. harpophylla* in the north, are often significant. *Callitris glaucophylla* is also prominent in the lower stratum in some areas and, as in the areas south of Byrock and around Cobar in western NSW, may be as tall as and co-dominant with *Eucalyptus*.

The understorey in the northern areas contains numerous other genera including lower eucalypts, *Eremophila*, *Carissa*, *Ventilago*, *Petalostigma*, *Alphitonia* and *Albizia*. The ground cover is primarily tussock grasses, though the hummock grass *Triodia mitchellii* is prominent in the northern *Eucalyptus melanophloia* open woodland.

Open woodland with hummock grasses M1H

This subform (**eM1tH**) occurs along the western margins of the *Eucalyptus* woodlands of central Qld. The characteristic trees include *Eucalyptus papuana*, *E. similis* and *E. whitei*; the latter two often occur in groves. *Triodia mitchellii* is the principal hummock grass, but tussock grasses may also be present.

Dawson gum over lancewood, central Qld
In several parts of eastern Australia this vegetation type (**eM1wL**) *is mapped where scattered eucalypts emerge above a dense low tree understorey. In central Qld the natural occurrences are mostly in mixed brigalow areas, but also involve other* Acacia *species such as* A. shirleyi *or lancewood, pictured here with emergent Dawson gum* (E. cambageana).

Yellow jacket open woodland over eastern spinifex
Eucalyptus similis, *with its distinctive yellow scaly bark, is found on sloping tablelands to the west of the Great Dividing Range in central Qld. It often forms groved open woodlands with a ground cover of eastern spinifex* (Triodia mitchellii), *as in this scene (far right) of* **eM1tH** *near Jericho.*

Open woodland with tussock grasses M1G

Examples of this subform (mainly **eM1yG**) are widespread in the present vegetation of eastern Australia within the general limits of open forests and woodlands. There are also a few isolated occurrences in northern and western Australia. Some examples, characterised by *Eucalyptus microtheca*, occur along intermittent watercourses in WA. An example near Darwin represents modification of the natural *Eucalyptus tetrodonta–E. miniata* forest (**eM3L**) of the Top End.

A large area of **eM1yG** in northern Qld is shown as essentially the same on both maps. This open woodland is characterised by such tree species as *Eucalyptus crebra*, *E. drepanophylla* and *E. dichromophloia*; the grassy layer includes *Themeda australis* and species of other genera such as *Bothriochloa*, *Aristida* and *Heteropogon*. This type has much in common with the adjacent grassy woodlands (**eM2G**) and may be associated with soils that are less favourable to tree growth.

Despite little active tree clearance in this area of northern Qld, the combination of burning and cattle grazing appears to have brought about an increase in *Heteropogon contortus* in the ground layer. This may in turn decline under heavy grazing and be replaced by the exotic *Bothriochloa pertusa* (Bisset 1980). The exotic shrubby weed *Ziziphus mauritiana* is invading some heavily grazed areas.

In much of the rest of eastern Australia the modification of former forests or woodlands has resulted in the development of many areas of grassy open woodland, characterised by relics of the tree layers of the previous vegetation including species of *Eucalyptus*, *Acacia*, *Callitris* and *Casuarina*. Some areas of **eM1yG** shown on the Present Vegetation map are generalisations of discrete remnant patches within largely cleared lands.

The numerous grasses include *Themeda australis* and species of *Bothriochloa* and *Aristida*; also *Dichanthium* in the north and *Stipa* and *Danthonia* in the south. Many of the ground layers have been further modified by the introduction of some exotic pasture species or by the entry of exotic weeds. Some seasonal cropping is also practised within these open woodlands in better watered areas.

The Natural Vegetation map shows a large area of grassy open woodland on the heavy soils along the upper tributaries of the Darling River. The principal tree species was *Eucalyptus microtheca* and the characteristic grass was *Astrebla lappacea* (**eM1aG**). However, the proportion of *A. lappacea* has been reduced by grazing and some areas have been further modified by clearing and by seasonal cropping.

The limited occurrences of this subform shown on the Natural Vegetation map in Vic. and on the Eyre Peninsula in SA have been replaced by seasonal crops in association with native or exotic pastures, or by exotic pastures only. They were floristically similar to the grassy woodlands (**eM2G**) existing today in the same general areas.

Open woodland with other herbaceous plants M1F

Examples of this subform (**eM1yF**, **eM1yfF**) are shown on the Present Vegetation map from north-eastern NSW to Tas. and SA. They result from the partial clearing of former forests and woodlands to enable the establishment of sown exotic pastures. Some seasonal cropping occurs in lower rainfall areas.

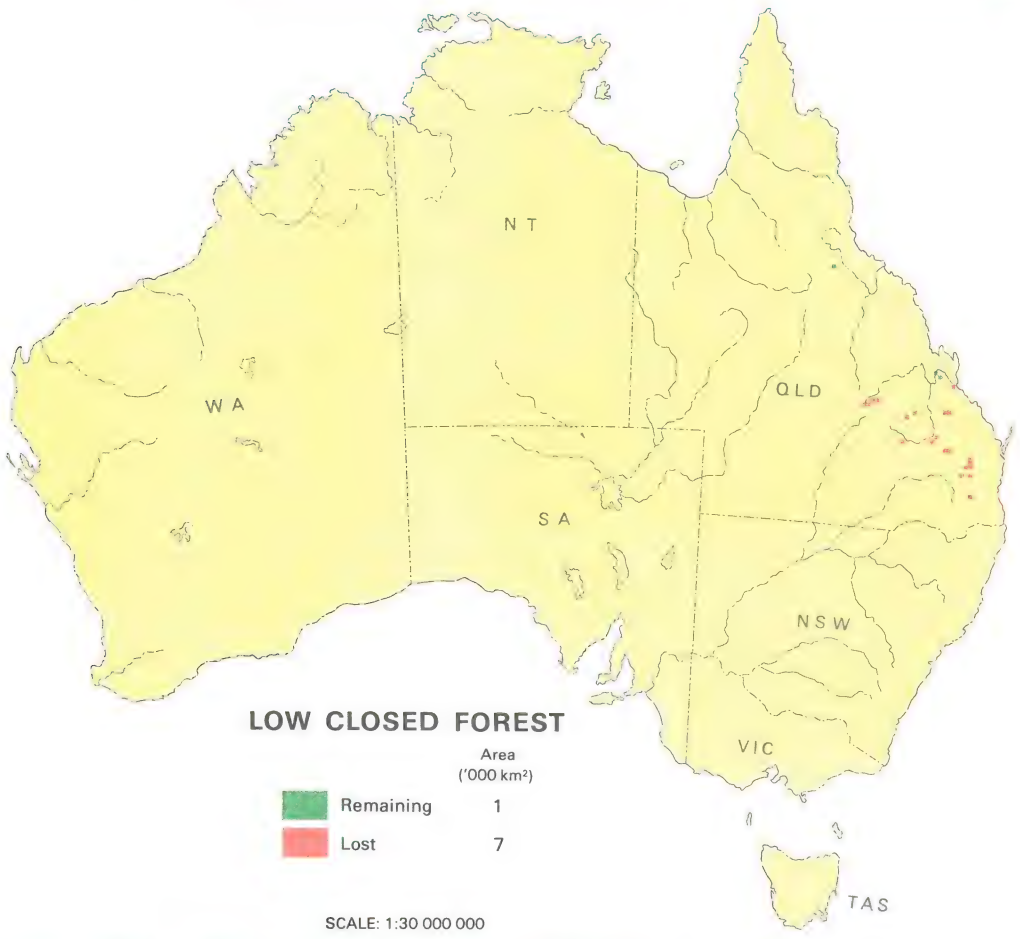
The ground layer is dominated by such perennial sward-forming grasses as *Phalaris aquatica*, *Lolium perenne* and *Paspalum dilatatum*. The first is more prominent under lower rainfalls; the last under higher rainfalls in warmer areas. There are varying proportions of legumes, notably the perennial *Trifolium repens* in higher rainfall areas and the seasonal *T. subterraneum* under lower or less reliable rainfalls. Some native grasses may persist, especially species such as *Bothriochloa macra* which are capable of adopting the sward-forming habit under grazing.

Open woodland of yellow gum with exotic pasture near Naracoorte (SA)
The natural grassy woodlands in the south-east of SA have been modified by tree thinning and the sowing of exotic pastures. This activity has created areas of open woodland, such as that pictured near Naracoorte, with yellow gum (Eucalyptus leucoxylon) *over a pasture of subterranean clover* (Trifolium subterraneum) *and a number of introduced grasses.*

Grassy open woodland in the New England area of NSW
The rolling country in the foreground would originally have carried woodland vegetation. Selective clearing and tree thinning have created the present agricultural open woodland (**eM1yG**) *dominated by white box* (Eucalyptus albens). *There has also been some clearing for cropping in the lower areas, while the higher ridges are still covered by woodland.*

Low trees

Low closed forest — Trees <10 m high; >70% foliage cover — L4



The low closed forests have a widespread but patchy distribution, especially across northern Australia. The main occurrences are on rich soils or basalt outcrops in Qld. In monsoonal areas they are mostly confined to small, fire-protected sites.

Some examples of low closed forest are allied to rainforest (**M4**) but occur under less favourable conditions. They correspond to the various types of 'thicket' described by Webb (1959, 1968) and, like the related rainforests, are floristically distinct from the surrounding sclerophyll vegetation. Under lower rainfalls they tend to be associated with basaltic or other fertile soils.

The mapped occurrences (**xL4**) are all in Qld. Most are 'microphyll vine thickets' of lesser floristic diversity and structural complexity than the corresponding vine forests. Their classification is complicated in many places by the presence of emergents, notably *Araucaria cunninghamii* near the coast and species of *Brachychiton* (including *B. rupestris*, the Qld bottle tree, and the deciduous *B. australis*) further inland.

The largest areas of this subform on the Natural Vegetation map were associated with fertile soils in south-eastern Qld. Most have been cleared for native or exotic pastures, or for seasonal cropping. The presence of remnant *Eucalyptus* or *Acacia* in some cleared areas reflects the mosaic nature of some of the units that are generalised as **xL4** on the maps.

Some other types of low closed forest consist of little more than a tree stratum dominated by a single species. The natural vegetation of Rottnest Island (near Perth) appears to have been dominated by *Callitris preissii* (**pL4**) (Seddon 1972). The present vegetation of this island has been modified to low shrubland (**xZ2G**). Many areas of mangroves also come into this structural category, but form part of the mosaic mapped as 'littoral complex'.

Vine thicket on rock outcrop, northern Qld
Many of the areas of **xL4** *in northern Qld grow in rocky outcrops such as this one near Tozers Gap. The largest present area of this type is found on the Great Basalt Wall, north-west of Charters Towers.*

Hoop pine scrub in south-eastern Qld
The picture on the far right shows a remnant patch of **xL4** *(foreground) in the Blackbutt Ranges of south-eastern Qld. It has a dense canopy of mixed low trees and occasional emergents of the native hoop pine* (Araucaria cunninghamii). *The hillside in the background has been cleared for a plantation of the hoop pine.*

Summit forest in the Bunya Mountains (Qld)
One of the last remaining examples of **xL4** *in southern Qld occurs in the Bunya Mountains. This low closed forest is distinguished by emergent bunya pine* (Araucaria bidwillii).

Low open forest

Trees <10 m high; 30–70% foliage cover **L3**

Several distinct forest types fall into this category. The most extensive are the lancewood (*Acacia shirleyi*) forests of the escarpment country in the NT and inland Qld. Dense and waterless thickets of lancewood in the Newcastle Waters area of the NT forced the explorer John McDouall Stuart to turn back in 1861 from his second unsuccessful attempt to reach the Gulf of Carpentaria.

Low open forest with shrubs L3S–L3Z

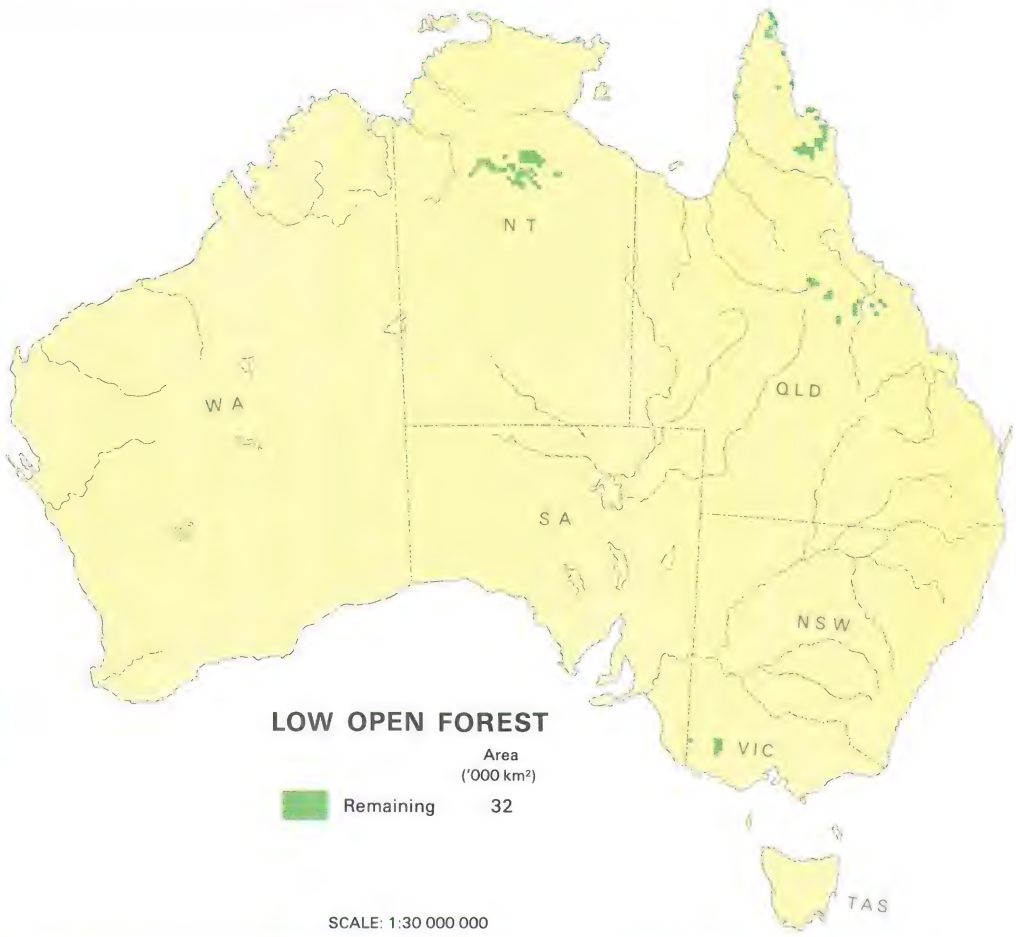
Those examples of this vegetation with a mixed upper stratum (**xL3S**, **xL3Z**) are found towards the northern end of Cape York Peninsula and are floristically diverse in both the low tree and shrub layers. Some appear to be intermediate in character between the adjacent forests (especially **eM3Z**) and open heaths (**xZ3G**). Some forests dominated by *Eucalyptus* in western Vic. (**eL3Z**), especially in the rocky ranges of The Grampians, are lower in stature than surrounding forests in the area (**eM3Z**), but are otherwise similar.

Low open forest with tussock grasses L3G

The mapped examples of this subform are all in northern Qld. The largest (**eL3G**) covers a belt of poorer dissected country between taller tropical forests and woodlands (**eM3L**, **eM2L**) to the west of Cooktown. The dominant tree species include *Eucalyptus cullenii* and *E. dichromophloia*; the grasses include *Themeda australis* and species of *Aristida* and *Heteropogon*. On low-lying areas there are also a few examples of *Melaleuca viridiflora* grassy low open forest (**mL3G**) with a ground layer of grasses and graminoids. The denser parts of the vegetation mapped as *Melaleuca* grassy low woodland (**mL2G**) around the head of the Gulf of Carpentaria grade into low open forest.

Low open forest with no significant lower stratum L3

The principal examples are low open forests of *Acacia shirleyi* (**wL3**) which are closely associated with shallow gravelly soils under annual rainfalls of about 500 mm or more in the NT and north-eastern Qld. Much of this vegetation consists of pure stands of the dominant species with virtually no understorey though these usually alternate with more open stands characterised by a grassy understorey and by an admixture of other trees (including species of *Eucalyptus*). Some stands in Qld include other species of *Acacia*.



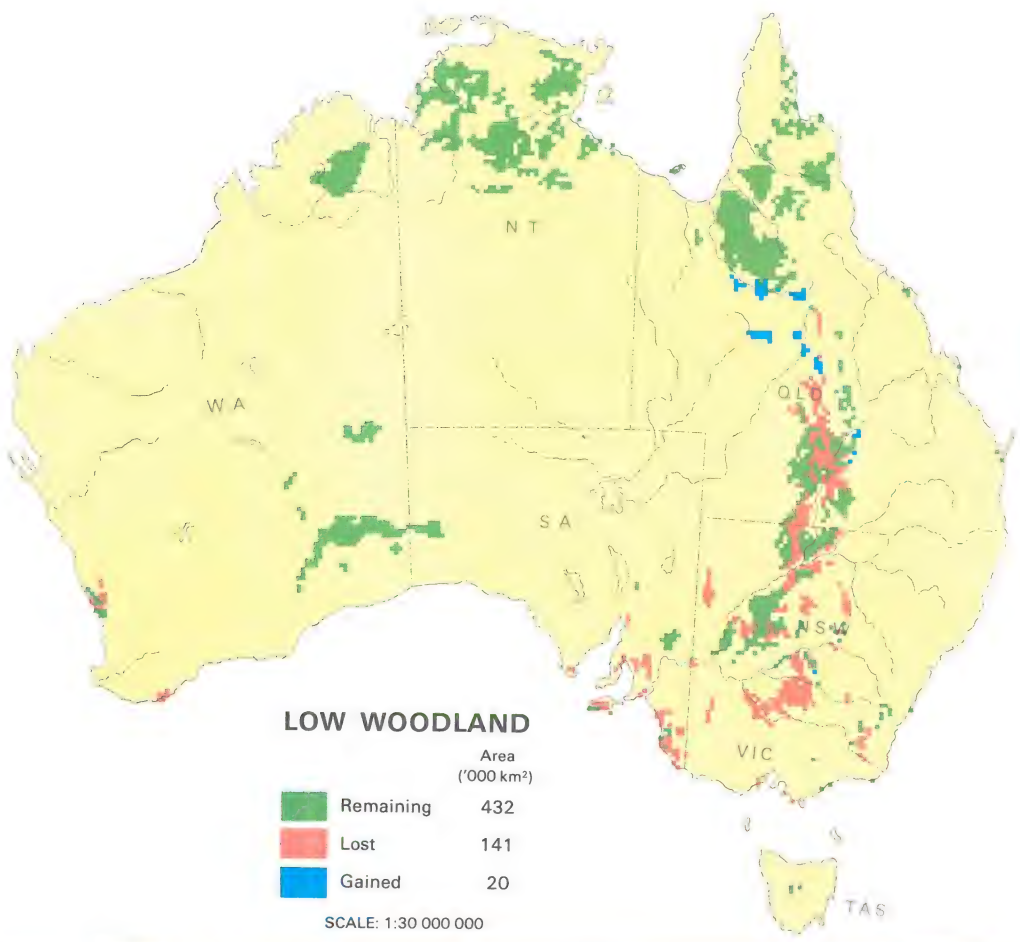
Lancewood forest, central Qld
Lancewood (Acacia shirleyi) *forms dense localised stands on shallow soils and scarps over a large area of the NT and Qld. Its range extends from the WA–NT border and southern Arnhem Land to the Darling Downs in south-eastern Qld. These forests (left) are characterised by fallen timber and little or no ground cover* (**wL3**). *Open forests of lancewood and of the related bendee* (A. catenulata) *in eastern Australia often reach the height limit for low trees (10 m), as in this stand near Dysart.*

***Eucalyptus* low open forest, northern Qld**
The deciduous white gum (Eucalyptus alba) *in flower stands out in the foreground of this dry-season scene from Cape York Peninsula (far left). This forest is similar in structure to those mapped as* **eL3G** *to the west of Cooktown. There is little evidence in this photo of the dense grassy understorey which is present for much of the year.*

Low woodland

Trees <10 m high; 10–30% foliage cover **L2**

As indicated by the variety of dominant genera shown on the maps, low woodlands are floristically very diverse. They occur extensively within the sub-humid and semi-arid zones of the continent. There are large areas of grassy low woodlands—notably those across the Top End of the NT with a range of *Eucalyptus* species and other low trees, and those south and east of the Gulf of Carpentaria in Qld with *Melaleuca* and other genera dominant. Besides the grassy low woodlands, there are numerous examples with shrubby or other understoreys.



Gidgee low woodland over tall shrubs
Gidgee (Acacia cambagei) *is found in western Qld and NSW and in the NT, where it occurs in grassy or shrubby low woodlands. This example, in central Qld, has been disturbed by grazing but shows a common shrubby understorey of* Eremophila mitchellii, *commonly known as budda or false sandalwood.*

Low woodland with tall shrubs L2S

This subform includes some isolated and distinctive vegetation types. Over much of Kangaroo Island (SA), for example, the natural vegetation ranged between low open forest and tall shrubland, with certain *Eucalyptus* species occurring in both. It is generalised on both maps as *Eucalyptus* low woodland (**eL2S**) with *E. baxteri* dominant, over a dense lower stratum of tall shrubs including *Banksia* species. More than half of the former area has now been cleared and sown to exotic pastures (**yfF3**).

Some of the low woodlands of *Acacia cambagei* in central Qld have an understorey of tall shrubs including *Eremophila mitchellii* (**wL2S**). On the riverine plain east of Hay (NSW) a large area was formerly covered by *Acacia pendula* low woodland with an understorey of *Atriplex nummularia* (**wL2S**). This has been replaced by native pasture (**yG2**) (Moore 1953).

Various coastal or hilly areas in eastern Australia are covered by low woodlands dominated by combinations of *Eucalyptus*, *Callitris*, *Acacia*, *Casuarina* or other genera, with understoreys consisting of a very wide range of species of tall shrubs (e.g. **epL2S**, **weL2S**).

Low woodland with low shrubs L2Z

Some of these low woodlands occur on poor sandy soils in coastal or near coastal locations in eastern Australia and in south-western WA. The major genera are *Eucalyptus* and *Banksia* (**eL2Z**, **bL2Z**, **ebL2Z**) sometimes with *Casuarina* (**ecL2Z**). Many of the *Eucalyptus* species also occur in neighbouring forests or woodlands.

The prominent species of *Banksia* include *B. serrata* in the south-east and *B. attenuata* in the south-west. The diverse low shrub stratum includes members of the families Proteaceae and Myrtaceae, which typically have small and sclerophyllous leaves. Species of *Xanthorrhoea* are often present and on wetter soils there may be a prominent ground layer of graminoids (Cyperaceae and Restionaceae).

Large areas in southern Australia have been cleared and sown to exotic pastures with some seasonal cropping, or used for the establishment of coniferous plantations.

Some areas of inland hill country in NSW carry low woodlands dominated by *Callitris glaucophylla* or *C. endlicheri* and species of *Eucalyptus*, with a varied low shrub layer (**peL2Z**, **epL2Z**). They have been modified in places to induce the growth of native grasses.

Several areas of saline or calcareous soils in southern Australia carry low woodlands of *Casuarina cristata* (**cL2Z**), often co-dominant with *Heterodendrum oleifolium* (**crL2Z**) and with an understorey of Chenopodiaceae.

Other examples of this subform, dominated by species of *Acacia* (**wL2Z**, **weL2Z**), are scattered throughout north-western NSW and central Qld. In some, especially those dominated by *Acacia aneura*, the appearance of a dense low shrub stratum of *Eremophila*, *Cassia* and *Dodonaea* species in the present vegetation is largely a consequence of pastoralism (Moore 1973). These 'woody weeds' have reduced the carrying capacity of grazing land over a wide area.

Large areas of calcareous earths to the north of the Nullarbor Plain are dominated by *Acacia papyrocarpa* and *A. aneura*, usually in association with *Casuarina cristata* (**wcL2Z**, **wL2Z**). Most of the low shrubs are Chenopodiaceae, especially species of *Maireana* and *Atriplex*. On the northern part of Wilson's Promontory (Vic.), the modification of former forest (**eM3L**) by repeated fires has created the present shrubby low woodland (**xL2Z**).

Low woodland with hummock grasses L2H

The rugged sandstone country of the central Kimberley region carries a low woodland characterised by *Eucalyptus phoenicea* and *E. ferruginea* over the hummock form of *Plectrachne pungens* (**eL2H**). *E. tetrodonta* and *E. dichromophloia*, which dominate the nearby grassy woodlands (**eM2G**), are also present. An adjoining area of shallow gravelly soils is dominated by species of *Melaleuca*, again associated with *P. pungens* (**mL2H**).

Patchy stands of *Acacia shirleyi* and *Macropteranthes kekwickii* west of Newcastle Waters are more open than those described under **wL3**. These have *Triodia pungens* in the ground layer and are generalised on the maps as **wL2H**.

Some stony scarp country in northern and central Qld carries low *Acacia* woodlands (**wL2**) of *A. shirleyi* to the north and *A. catenulata* and *A. petraea* further south. Lower strata of hummock or tussock grasses may be present but are typically very sparse.

Low woodland with tussock grasses L2G

Grassy low *Eucalyptus* woodlands (e.g. **eL2G**, **emL2G**) are fairly widespread in tropical northern Australia but more scattered in the south-east. They tend to occur under lower rainfalls or on poorer soils than the corresponding woodlands (e.g. **eM2G**).

Eucalyptus dichromophloia is prominent in the northern low woodlands, together with *E. tectifica* in the NT and *E. cullenii* in northern Qld. *Callitris intratropica* and species of *Melaleuca* are co-dominant with *Eucalyptus* in some places; species of *Terminalia* are also prominent. Grasses include *Themeda australis* and species of *Aristida*, *Heteropogon* and *Sorghum*.

The distribution of the northern low woodlands is little changed except for small cleared areas south of Darwin (**xS1yG**) and near Proserpine in Qld (**vG4**). Pastoralism has had a similar effect to that described under **M2G**.

The grassy low woodlands of south-eastern Australia have largely been cleared for pastures or cropping. The dominant species in the remaining areas include *Eucalyptus populnea* in the north, *E. pauciflora* in the south-east and *E. odorata* in the west, together with *E. largiflorens* on many inland alluvial flats. The grasses include *Themeda*, *Poa*, *Danthonia*, *Aristida*, *Stipa* and *Chloris*. Some *Eucalyptus largiflorens* woodlands formerly had a low shrub understorey of Chenopodiaceae.

Melaleuca low woodlands (**mL2G**), dominated by several species including *M. viridiflora*, occur on sandy alluvial plains across the north-east, especially in the Qld Gulf Country. The grasses include *Aristida, Chrysopogon* and *Eriachne*. An area dominated by *M. lanceolata* is mapped in swampy country in south-eastern SA.

Acacia aneura is the principal species of the low woodlands (**wL2G**, **weL2G**) in southern Qld and north-western NSW. These are a lower-rainfall extension of the *A. aneura* forests (**wM3**, **weM3**) and occur on the same distinctive red earths. As in the forests, *A. aneura* is often accompanied by *Eucalyptus populnea* or *E. melanophloia*, or sometimes by *Callitris glaucophylla* (**wpL2G**). Under the woodland canopy there is a grass stratum including *Thyridolepis mitchelliana* and species of *Eragrostis* and *Aristida*. Across central and western Australia, *Acacia aneura* is generally found as a tall shrub, but there is at least one example of *A. aneura* low woodland around the Warburton Range of WA (Beard 1974).

Other species of *Acacia* also form grassy low woodlands. In particular, *A. argyrodendron* and *A. cambagei* woodlands occur along the eastern margin of the *Astrebla* grasslands in central Qld. The isolated area mapped as **weL2G** east of Newcastle Waters is a mosaic of *Acacia shirleyi*, *Eucalyptus dichromophloia* and *E. leucophloia* over a ground layer of *Chloris*, *Aristida* and *Enneapogon* species.

Acacia low woodlands were formerly more extensive in inland Qld and NSW but thinning and clearing to increase native pasture growth has reduced large areas to **wL1yG** or **weL1yG**. In other areas native grasses have been reduced under grazing, especially by sheep. A great increase in low shrubs has created areas of **wL2Z** or **weL2Z** from former grassy woodlands around Bourke (NSW). To improve pasture productivity drought tolerant exotic grasses have been established in some cleared areas, for example the area shown as **yG2** around Blackall (Qld).

Some of the present areas of **wL2G** in north-central Qld represent a new and distinctive vegetation type. The exotic *Acacia nilotica* was introduced as a shade and fodder tree to the *Astrebla* grasslands but has become a weed (Bolton and James 1985). It is now widespread in these grasslands and has also appeared in some adjacent vegetation types. Heavily infested properties lie along the railway from Hughenden to west of Julia Creek, and around Winton. The cover of *Acacia nilotica* within these areas often exceeds 10%.

Some sandy or calcareous soils on the plains in western NSW are covered by low woodlands of *Casuarina cristata*, sometimes with *Heterodendrum oleifolium* as a co-dominant (**cL2G**, **crL2G**). The grasses include species of *Stipa*, *Enneapogon* and *Eragrostis*. There is a similar example in the salt country of WA. Some stands have been thinned out under pastoralism and an area near Griffith has been cleared for cropping. Further north a more mixed low woodland (**xL2G**) includes not only the above species but also others from neighbouring units, such as *Callitris glaucophylla*, *Acacia loderi*, *A. aneura* and *Flindersia maculosa*. A smaller mixed area on the Murray River near Renmark (SA) has been modified by settlement.

In the NT some mixed low woodlands (**xL2G**) contain not only *Eucalyptus* but also *Melaleuca*, *Acacia*, *Terminalia* and *Erythlophleum*. Again, the *Melaleuca* grassy low woodlands to the south-east of the Gulf of Carpentaria (**mL2G**) grade into similar woodlands with various dominants including species of *Lysiphyllum*, *Albizia*, *Grevillea* and *Terminalia*.

Low woodland with other herbaceous plants L2F

The only mapped example (**eL2F**) is a coastal area of former shrubby low woodland (**eL2Z**) in the present vegetation of south-eastern SA. It is still dominated by *E. baxteri* but the understorey has been modified and is now largely exotic grasses, including *Lagurus ovatus*, and the native fern *Pteridium esculentum*.

Low woodland of snow gum in the Snowy Mountains
Low woodlands of Eucalyptus pauciflora *with a diverse low shrub stratum* (**eL2Z**) *are prominent on mountain soils above 1500 m in southern NSW and Vic. Such low woodlands also occur at lower altitudes, especially on sites receiving cold air drainage. There is often a well developed ground layer dominated by species of* Poa. *Areas of comparable vegetation, dominated by* Eucalyptus coccifera, *occur at somewhat lower altitudes in Tas.*

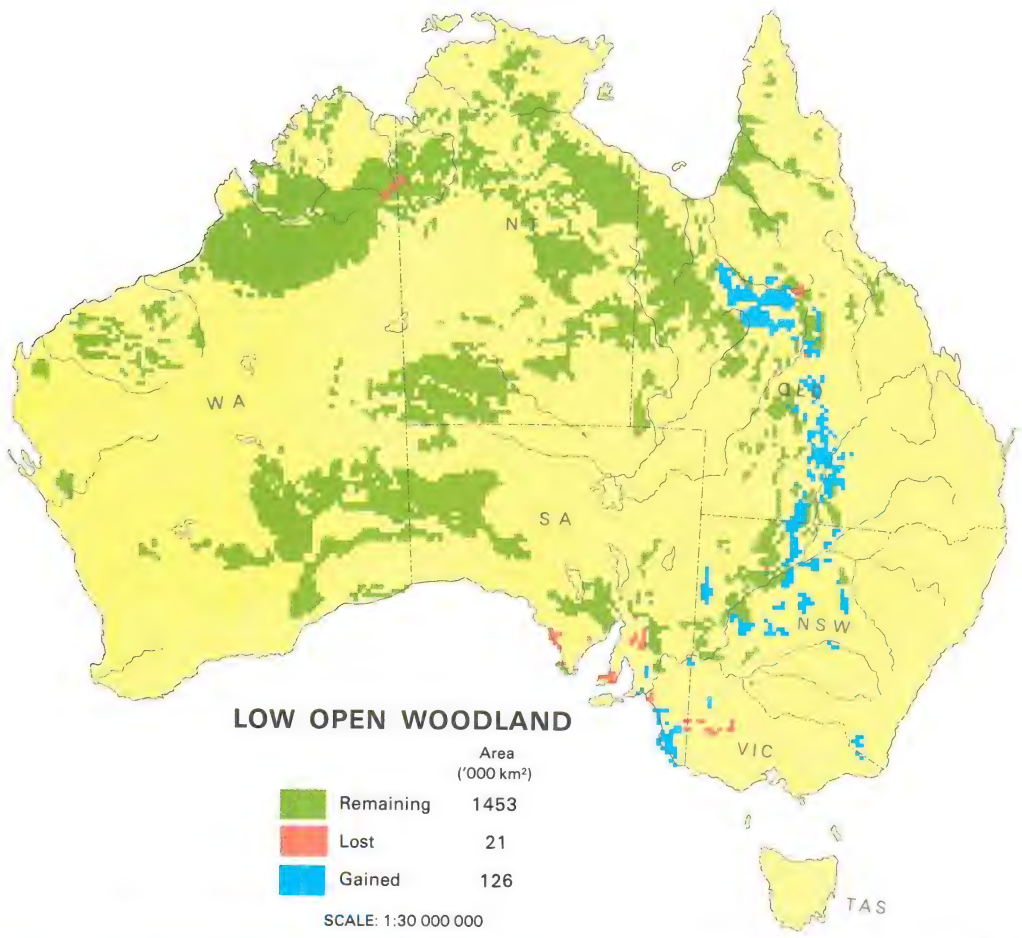
Low woodland of mulga near Eulo (Qld)
Mulga (Acacia aneura) *low woodlands are widespread on the red earth country of south-western Qld. On stony residual country further west, mulga forms tall open shrublands. The usual ground cover of sparse tussock grasses is absent from this grazed stand, photographed during a period of drought.*

Black box grassy low woodland
Black box (Eucalyptus largiflorens) *is widespread on clay floodplains and lake basins in western NSW and Vic., where it usually occurs behind fringing woodlands of river red gum. Most stands of black box now have a ground cover of grasses, although many previously also had an understorey of chenopods, including old man saltbush* (Atriplex nummularia).

Low open woodland

Trees <10 m high; <10% foliage cover **L1**

Low open woodlands are found throughout much of inland Australia where the scarcity of water and poor soils limit the height and density of trees. Eucalypts and acacias commonly dominate the tree layer but other genera also appear on the maps. The most widespread subforms are those with a hummock or tussock grass lower stratum, but shrubby or other herbaceous understoreys also occur. The ground layer of low open woodlands is often the most conspicuous feature of these landscapes, particularly when the trees are very sparsely scattered.



Low open woodland of western myall over bluebush in SA
Western myall (Acacia papyrocarpa) *is a long-lived species which forms low open woodlands* (**wL1kZ**) *or tall open shrublands, associated with chenopod shrubs such as pearl bluebush* (Maireana sedifolia). *One major occurrence is found on calcareous or sandy soils in the 125–300 mm annual rainfall zone north-west of Spencer Gulf (SA). It is also prominent along the margins of the Nullarbor Plain in WA. Most of the western myall plains in SA are used for sheep grazing and the combination of domestic stock and rabbits has seriously depleted the natural regeneration of the species.*

Low open woodland with tall shrubs L1S

This vegetation occupies intermediate positions between woodland and shrubland. There is a wide range of tree species, with *Acacia* prominent among the shrubs.

The 'pindan' vegetation, characterised by a dense shrub stratum beneath low eucalypts (**eL1wS**), occurs over a large area of earthy sands to the south-west of the Kimberley region in WA. *Eucalyptus dichromophloia* is prominent in the tree stratum and *Acacia* (especially *A. tumida* and *A. eriopoda*) in the shrub stratum. In the drier areas further south-west the tree layer diminishes, leaving only the shrub layer (**wS3H**). The areas of **eM2S** north of Broome and Derby are higher-rainfall equivalents of the pindan vegetation. There are also sparse tussock grasses including *Chrysopogon* and *Sorghum* species, and *Plectrachne pungens*, though the hummock grasses *Triodia pungens* and *Plectrachne schinzii* increase with decreasing rainfall.

Across the southern inland this subform occurs on a range of soils, mostly in areas of low relief but also in the Flinders Ranges. The trees include *Callitris glaucophylla*, *Casuarina cristata* and species of *Eucalyptus* (e.g. **pL1wS**, **ecL1wS**, **xL1xS**) over a variety of tall shrubs including *Acacia aneura* and *E. socialis*. A former area of **weL2S** in central Qld is now **wL1xS**.

Low open woodland with low shrubs L1Z

Examples of this subform (**xL1xZ**, **eL1xZ**, **eL1kZ**) occur on the margins of the *Astrebla* grasslands (**aG2**, **aG3**) on the Barkly Tableland in Qld and NT. *Eucalyptus argillacea* and *E. terminalis* are prominant in the tree layer, along with species of *Terminalia* and *Lysiphyllum*. The shrubs include species of *Acacia*, *Cassia* and *Carissa*, with *Chenopodium auricomum* in low-lying areas.

Other examples are found across the southern interior of Australia, especially on calcareous soils in areas with an annual rainfall below 300 mm. The characteristic trees include *Acacia papyrocarpa*, *Casuarina cristata* and *Myoporum platycarpum*, with *Eucalyptus largiflorens* and *Heterodendrum oleifolium* further east. The low shrubs are mostly chenopods, especially species of *Atriplex* and *Maireana* (e.g. **wL1kZ**, **qcL1kZ**, **eL1kZ**, **crL1kZ**).

The shrub layer has been reduced by grazing in some areas, such as the former areas of **qL1kZ** and **cL1kZ**, north-east of Adelaide, now coded as **qL1yG** and **cL1yG**. At the southern end of Eyre Peninsula an area of *Melaleuca lanceolata* and *Allocasuarina verticillata* (**mcL1xZ**) has been partly replaced by seasonal pastures (***yfF3***) and crops.

Present areas of this vegetation between Cobar (NSW) and Cunnamulla (Qld) represent the appearance of a dense layer of shrubs (**wL1xZ**, **weL1xZ**, **ewL1xZ**, **wpL1xZ**), the 'woody weeds' referred to under **L2Z**, in former grassy woodlands.

Low open woodland with hummock grasses L1H

These open woodlands are found on sandplains, dunefields and shallow stony soils. Although the hummock grass layer is conspicuous, the plants are well spaced so the overall cover is relatively sparse.

Eucalyptus is widespread in the tree stratum, with many examples of **eL1tH** in the 200–800 mm annual rainfall range across northern Australia. Species include *E. dichromophloia*, *E. terminalis*, *E. setosa*, *E. leucophloia* and *E. brevifolia*. The hummock grasses include a number of *Triodia* species, such as the widespread *T. pungens*, *T. wiseana* on stony soils in the Hamersley Range and the Kimberley region and *T. mitchellii* in the easternmost areas in central Qld. *Plectrachne schinzii* is found in some sandy areas and *P. pungens* in the Kimberly.

Eucalyptus gongylocarpa and *Triodia basedowii* are major species in the Great Victoria Desert (WA, SA), where annual rainfall is usually less than 150 mm. Sparse tall shrubs also occur, notably *E. youngiana* and *Acacia aneura*. Across the sandy country of western-central Australia, for example around Lake Amadeus and the Petermann Ranges, there are low open woodlands of *Allocasuarina decaisneana* with scattered shrubs and an understorey of *T. basedowii* (**cL1tH**).

In the north-west of the Great Sandy Desert, *Eucalyptus* is replaced by *Owenia reticulata* (**oL1tH**). Some other northern areas are dominated by a range of genera including *Grevillea* and *Lysiphyllum* (**xL1tH**). The ranges of central Australia carry such tree species as *Atalaya hemiglauca*, *Hakea lorea*, *Callitris glaucophylla* and *E. papuana*, over several species of *Triodia*. There is an area of **mL1tH** in the Top End of the NT.

L1

Low open woodland with tussock grasses L1G

This subform is found on heavier soils than that with a hummock grass understorey, mainly in low rainfall areas. Other examples occur naturally within the limits of taller woodlands, where poor or heavy clay soils limit tree growth.

Across northern Australia *Eucalyptus dichromophloia* is widespread, as are *E. terminalis* and *E. pruinosa* under lower rainfalls (**eL1yG**). The grasses include *Themeda australis*, *Sehima nervosum*, and species of *Chrysopogon*, *Sorghum* and *Heteropogon*, along with *Aristida* in drier areas. *E. tectifica* also occurs in the upper stratum in the Kimberley region and the Top End, as does *Plectrachne pungens* in the ground layer. The tussock form of *P. pungens* is the principal grass in the King Leopold Ranges in WA (**eL1tG**) and, in the past, was probably kept in this state by Aboriginal burning.

Domestic stock or feral animals (Graham and others 1982) have significantly changed several areas of **eL1yG** in the grazed lands of the north-west. Much of the native vegetation of the upper Ord River catchment, for example, has been eliminated though the area is now being rehabilitated with sown exotic grasses (**yG2**).

Eucalyptus microtheca is the characteristic tree on floodplain country right across the north and inland, while *E. largiflorens* is present in the south-east. There is often a range of grasses (**eL1yG**, **ewL1yG**) but *Astrebla* or *Dichanthium* may be dominant (**eL1aG**, **eL1dG**).

There are examples of *Eucalyptus* grassy low open woodlands in south-eastern Australia on both maps. The present areas result from changes to more dense natural vegetation; while the naturally occurring areas have now been replaced by pastures and crops.

The major natural occurrences dominated by *Acacia* are in western Qld and the NT, generally on clay and calcareous soils within the 100–400 mm annual rainfall range. Principal species are the closely related *A. cambagei* and *A. georginae*, the latter being more prominent in the west. *A. tephrina* is often associated with *A. cambagei* in the east. Grasses include *Astrebla* (**wL1aG**) or *Dichanthium* (**wL1dG**), or a range of genera such as *Aristida* and *Enneapogon* (**wL1yG**).

The *Acacia* low woodlands of inland Qld and the Barrier Range in western NSW have been reduced to open woodlands (**wL1yG**, **weL1yG**). The recent spread of the exotic *A. nilotica* over *Astrebla* grasslands in Qld has created a large additional area of **wL1aG**.

Alluvial plains on Cape York Peninsula support *Melaleuca viridiflora* low open woodlands over a range of grasses including *Eriachne*, *Sorghum* and *Panicum* (**mL1yG**, **meL1yG**). Former low open woodlands of *M. lanceolata* over *Stipa* and *Danthonia* in coastal areas of SA have been replaced by pastures and crops.

The area dominated by *Casuarina* open woodland in western NSW has increased in the present vegetation through changes to natural woodlands or shrubby open woodlands (**crL2G**, **cL1kZ**). The dominant species is *C. cristata* (**cL1yG**), sometimes with *Heterodendrum oleifolium* as a co-dominant (**crL1yG**), over *Eragrostis* and *Stipa*. In SA and Vic., former areas of **cL1yG** dominated by *Allocasuarina verticillata* or *A. luehmannii* over *Stipa* and *Danthonia* now carry pastures or crops.

Across northern Australia the characteristic trees of low open woodlands with several tree genera (**xL1yG**) include *Terminalia*, *Lysiphyllum* and *Eucalyptus*, with the distinctive *Adansonia gregorii* in the Kimberley region. The grasses include *Sorghum*, *Chrysopogon*, *Astrebla*, *Dichanthium* and *Eriachne*. Further south, these trees are replaced by such species as *Atalaya hemiglauca*, *Ventilago viminalis* and various acacias. The ground layer also differs, with a variable cover of grasses, such as *Aristida* and *Enneapogon*, and forbs, including Chenopodiaceae and Asteraceae. Isolated examples of **xL1yG** in SA have *Callitris glaucophylla*, *Casuarina cristata* and *Eucalyptus* species over such grasses as *Stipa*, *Danthonia* and *Aristida*.

Low open woodland with other herbaceous plants L1F

The natural occurrences of this subform (e.g. **eL1kF**, **wL1kF**) are on inland floodplains in Qld and NSW. The main species are *Eucalyptus ochrophloia*, *E. microtheca*, *E. largiflorens* and *Acacia cambagei*. The persistent forbs include *Sclerolaena*, *Atriplex* and *Maireana*.

On the Present Vegetation map the additional areas dominated by *Eucalyptus* in SA and Vic. (**eL1yfF**) result from the partial clearing of low woodlands (**eL2Z**, **eL2G**) for sown pasture. Some natural treeless plains are generalised within the largest area of **eL1yfF** (mainly *E. fasciculosa*) in south-eastern SA. There is some cropping within this type and the pastures contain such grasses as *Phalaris aquatica* and *Dactylis glomerata*, along with the legumes *Trifolium subterraneum* and *Medicago sativa*.

Low open woodland with no significant lower stratum L1

Natural occurrences of this subform on broken sandstone country in Arnhem Land have a very sparse cover of small trees, shrubs and hummock grasses fragmented by areas of bare rock. Typical trees are *Eucalyptus miniata, E. dichromophloia, E. phoenicea, E. bleeseri* and *E. papuana*. These areas are therefore coded as **eL1**.

Two areas of **eL1yG** in northern WA on the Natural Vegetation map are now shown with less than 10% ground cover (**eL1**). They are indicative of more widespread changes due to grazing. In central Qld patchy areas of *Acacia catenulata, A. petraea* and *A. shirleyi* low woodland (**wL2**) on rocky outcrops are generalised as **wL1**.

Low eucalypts on the Arnhem Land plateau
The rugged sandstone and quartzite country of Arnhem Land (NT) supports a variety of vegetation, from stunted open woodland on rock outcrops to patches of rainforest in the sheltered gorges. On the rocky tops of the dissected plateau there is a sparse low open woodland of such species as Eucalyptus dichromophloia, E. bleeseri, E. miniata *and* E. phoenicea (**eL1**) *with scattered shrubs and a patchy cover of the hummock grass* Triodia microstachya.

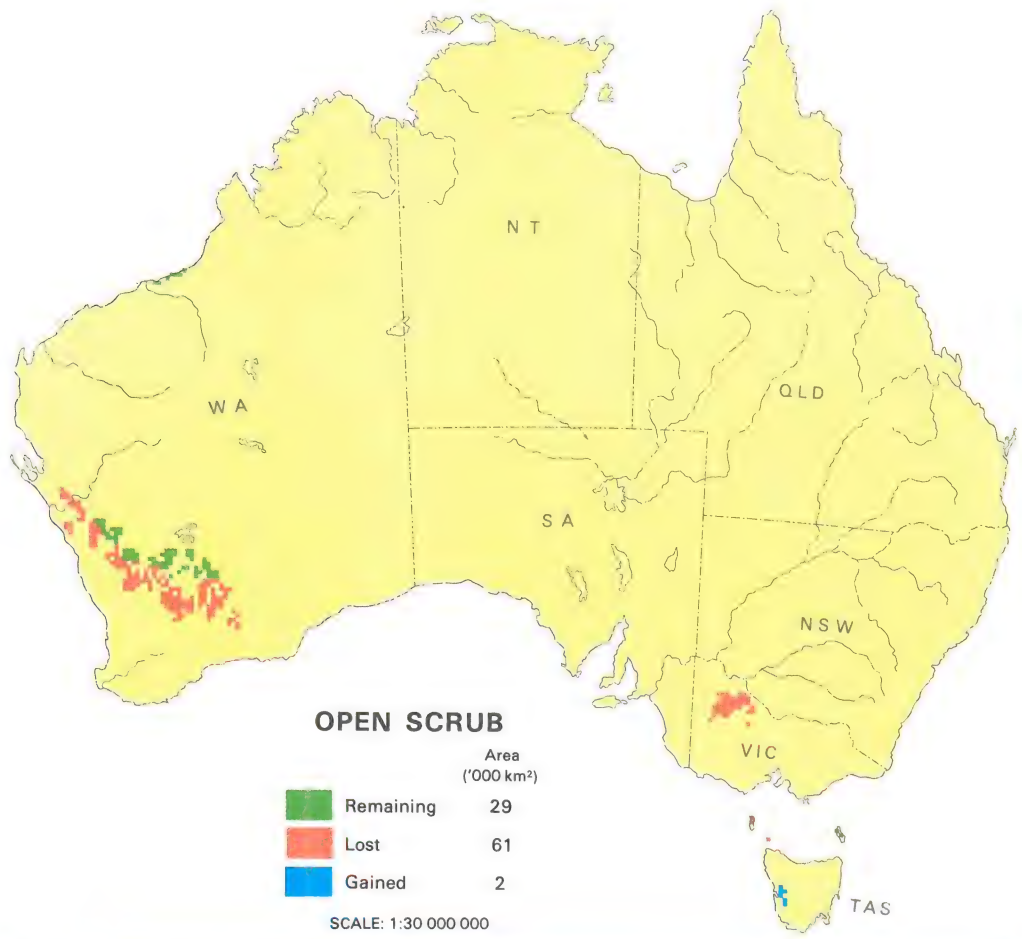
Desert sheoak over spinifex in central Australia
Wide areas of desert sand country in the south-west of the NT and extending into WA and SA, carry a patchy low open woodland of the distinctive desert sheoak (Allocasuarina decaisneana) *with scattered shrubs and a ground cover of lobed spinifex* (Triodia basedowii). *Most hummock grasses are highly flammable and these landscapes are subject to frequent fires. Some are started by lightning and others by landholders, both Aboriginal and European.*

Fire in tropical low open woodland
Low intensity fires are a regular dry season occurence throughout the grassy woodlands and open woodlands of northern Australia. This photo shows a ground layer fire creeping through the grass understorey of a mixed low open woodland (**xL1yG**) *photographed near Georgetown in inland northern Qld. The grassy low open woodlands of northern Australia are similar to the tree savanna vegetation of Africa and South America.*

Tall shrubs

Open scrub — Shrubs >2 m high; 30–70% foliage cover — S3

The open scrubs are dense formations of tall shrubs and, like the related heaths, are found on low nutrient or waterlogged soils. As closed scrubs (**S4**) are more restricted and often occur as dense patches within open scrub, they have not been separated from **S3** on the maps.



Mallee open scrub
At its south-eastern margin in Vic. the mallee vegetation achieved open scrub density (more than 30% foliage cover) with an understorey of tussock grasses. Nearly all of this vegetation has now been cleared for cropping or grazing. The photo shows a remnant patch of mallee open scrub near Sea Lake, western Vic.

Casuarina open scrub
The open scrubs of south-western WA occur on sandy or gravelly soils inland of the wheatbelt. This kind of vegetation is dominated by a number of Acacia *and* Allocasuarina *species, including* Allocasuarina campestris *and* A. acutivalvis. *The increased frequency of fires near settled areas has changed parts of this formation to scrub-heath. This photo illustrates a disturbed open scrub near Hyden (WA) with regenerating shrubs in the foreground.*

In eastern Australia open scrubs occur on sandy areas and rocky exposures along the coast and formerly also covered a large area of calcareous soils in western Vic. In WA they extend into drier areas on sandy or gravelly soils. *Acacia* and *Casuarina* scrubs were formerly widespread from north of Geraldton to near Norseman in the south-west, while to the north pindan scrubs occur on the coastal plains east of Port Hedland.

Various genera dominate open scrub vegetation, including *Acacia, Banksia, Casuarina, Melaleuca, and Leptospermum. Eucalyptus* is also a dominant, typically in the distinctive multi-stemmed 'mallee' shrub form. The dense mallees which once covered large areas west of Swan Hill (Vic.) formed open scrubs.

Open scrub frequently forms mosaics with other vegetation types such as woodland, closed scrub, various combinations of shrubland and heath in areas regenerating after fire, and sedgelands in waterlogged areas.

Open scrub with low shrubs — S3Z

The largest mapped areas of this subform are in south-western WA, on infertile sandy soils in a zone where annual rainfall ranges from about 225 mm to more than 300 mm. The tallest stratum is dominated by numerous species of *Acacia* or *Allocasuarina*. Only the type dominated by *Acacia* appears on the Present Vegetation map but there is a wider range on the Natural Vegetation map (**wS3Z**, **wcS3Z**, **cwS3Z**, **cS3Z**). The dominant species include *A. acuminata*, *A. coolgardiensis*, *A. neurophylla*, *A. quadrimarginea* and *A. resinomarginea* as well as *Allocasuarina acutivalvis*, *A. campestris* and *A. corniculata*.

Some stands shown on the Natural Vegetation map (**ecS3Z**) also include mallees such as *Eucalyptus foecunda* and *E. transcontinentalis*. The lower stratum consists of sclerophyllous shrubs, many of them ericoid (heath-like), from a range of families including Myrtaceae and Proteaceae.

Many of these open scrubs have been modified under settlement. Some areas show structural changes related to frequent burning (**cwS2Z**, **xZ3**), while others have been cleared and sown to seasonal crops and pastures (***yf*F3**).

There are only a few small mapped areas in eastern Australia. On poor stony soils in central Vic. there are examples of natural or modified open scrubs dominated by shrubby species of *Eucalyptus* (mallees such as *E. behriana* and *E. viridis*), with a lower stratum that includes species of *Acacia* and *Cassinia* (**eS3Z**).

Parts of Fraser Island (Qld) and the Bass Strait islands carry vegetation mosaics generalised as mixed open scrub (**xS3Z**). The dominant genera include *Banksia*, *Casuarina*, *Acacia* and *Melaleuca*. Some former examples on the Bass Strait islands have been thinned out by disturbance (**xS2Z**) or cleared and sown to exotic pastures (**yfF3**).

Open scrub with hummock grasses — S3H

The pindan vegetation of the Kimberley region is mapped in part as *Eucalyptus* low open woodland with a lower stratum of *Acacia* tall shrubs (**eL1wS**). Under the lower rainfall further south, there are few trees and the tall shrubs become dominant. Thus the vegetation is mapped as *Acacia* open scrub with hummock grasses (**wS3H**). The same pindan species of *Acacia* are present but *A. pachycarpa* may be more prominent. The ground layer is dominated by the hummock grasses *Plectrachne schinzii* and *Triodia pungens*.

Open scrub with tussock grasses or graminoids — S3G

The Natural Vegetation map shows several examples in north-western Vic. dominated by mallee species of *Eucalyptus*. Most mallee vegetation is mapped as tall shrubland (**eS2**), but shrub density was higher and foliage cover was more than 30% at the south-eastern margin of the mallee in Vic. This dense mallee, which usually had a sparse grass understorey, is mapped as open scrub (**eS3G**).

Most former areas of this vegetation type have been cleared for seasonal cropping and native pastures. Small unmapped relic stands contain numerous species of *Eucalyptus*, including *E. dumosa* and *E. oleosa*, over such tussock grasses as *Stipa* and *Danthonia*. Sparse low shrubs are also present in some places.

As discussed under closed forest, a large area of open scrub (**xS3G**) in western Tas. appears to be the product of a series of fires in former *Nothofagus* forest (**nM4**). There are numerous shrubs, including species of *Acacia* and *Leptospermum*, with a diverse ground layer containing graminoids such as Cyperaceae and Restionaceae.

Tall shrubland

Shrubs >2 m high; 10–30% foliage cover **S2**

Two of Australia's best known inland vegetation types—mallee and mulga—occur within this category, though they have been extensively modified by European land use. Much former mallee land now lies within the wheatbelt and large areas of mulga tall shrubland have been reduced to open shrubland by more than a century of grazing.

Tall shrubland with low shrubs S2Z

This widely occurring subform is most commonly dominated by mallee eucalypts or by *Acacia*. *Eucalyptus* tall shrublands with low shrubs (**eS2Z**) are widespread across southern Australia, mainly within the 200–450 mm annual rainfall range and on a variety of soils including calcareous earths, sands and alkaline duplex soils. Dominant species include the widespread *E. oleosa*, *E. gracilis*, *E. incrassata* and *E. foecunda*, and also *E. eremophila* in WA. Other genera are occasionally co-dominant, for example species of *Myoporum* (**eqS2Z**) or *Melaleuca* (**meS2Z**).

Under higher rainfalls the low shrubs are usually dense, typically sclerophyllous and often ericoid. This understorey is floristically diverse and includes members of the Proteaceae and Myrtaceae (especially species of *Melaleuca*). With decreasing rainfall it contains fewer species and is more open. There may also be sparse tussock grasses such as *Stipa*, or the hummock grasses *Triodia irritans* or *T. scariosa*. Towards the lower rainfall limit the Chenopodiaceae, including *Atriplex* and *Maireana*, tend to dominate. Soil factors also play a part in understorey distributions.

The distribution of this vegetation is much more extensive on the Natural Vegetation map. Some areas have been modified by thinning, burning and sheep grazing. Where annual rainfall exceeds 280 mm, most stands have been cleared and sown to seasonal crops, with native or exotic pastures.

Acacia tall shrublands of this subform (**wS2Z**) occupy much of central-western WA and parts of the interior of SA. They occur within the 150–250 mm annual rainfall range on various soils, including red and calcareous earths, alkaline duplex soils, sands and shallow soils over rock or hardpan. *A. aneura* is the most widespread dominant species, but is replaced by *A. ramulosa* and *A. linophylla* on the southern and western margins of this vegetation type, and by *A. xiphophylla* in the north-west.

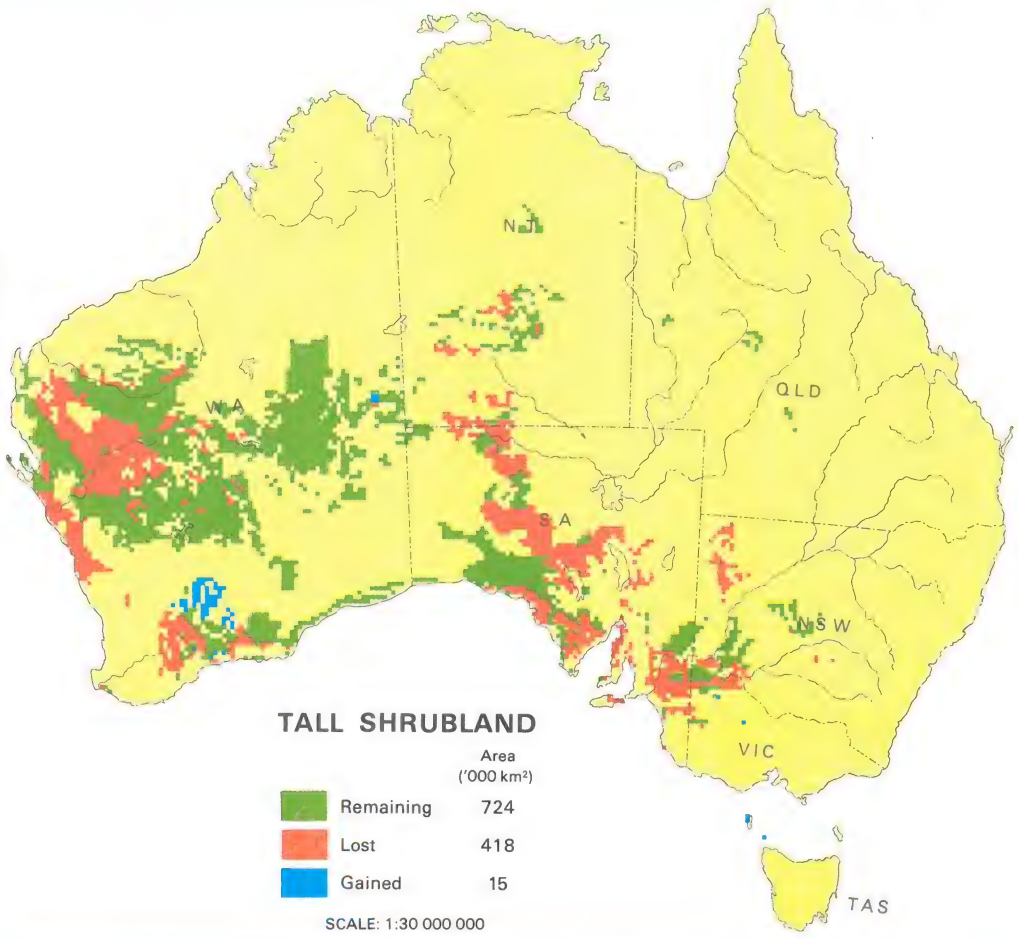
The growth form of *A. aneura* is generally that of a tall shrub, although the tree form is attained on favourable sites. The low shrubs include numerous *Eremophila* species. There is a variable ground layer of tussock grasses (such as *Aristida*, *Danthonia* and *Eragrostis*) and forbs (including species of *Ptilotus* and of Asteraceae). On calcareous and saline soils, especially in SA, *Atriplex* and *Maireana* dominate the low shrub layer.

In many areas within the *Acacia* tall shrublands grazing has reduced either the upper stratum (e.g. to **wS1kZ**), or the low shrub stratum—especially palatable species of *Eremophila* (e.g. to **wS2G**). Over a large area in WA there has been a substantial reduction of both shrub strata, and also the ground layer (Wilcox and McKinnon 1972). These former areas of **wS2Z** are now coded as **wS1**.

Examples with a range of genera in the tallest stratum (**xS2Z**) are associated with infertile soils, including some coastal dune systems. Those which occur on sandy soils in the south-west of WA correspond to the 'scrub-heaths' of Beard (1969). *Banksia*, *Grevillea* and *Acacia* are common in the tallest stratum. The dense lower stratum consists of many different sclerophyllous shrubs from such families as Proteaceae and Myrtaceae. Along the coast of NSW and southern Qld, patches of similar vegetation occur on very infertile soils within the mapped limits of *Eucalyptus* open forests.

Scrub-heaths were much more prominent in the natural vegetation. They are naturally subject to fires and pass through a dense low shrub stage during regeneration. Large areas in WA are now coded as **xZ3** because the frequency of recent fires has prevented the development of the mature stage. Apart from areas modified by frequent burning, there are others which have been cleared and sown to seasonal crops and pastures (***yfF3***). The infertility of the soil is overcome by massive applications of fertiliser.

A similar type (**xS2Z**) occurred in the natural vegetation of the Flinders Ranges in SA. The tall shrubs included species of *Acacia*, *Eucalyptus* and *Myoporum* over such low shrubs as *Eremophila*, *Cassia* and *Dodonaea*. The ground layer included grasses (*Stipa*, *Danthonia* and *Enneapogon*) and forbs such as *Sclerolaena*. The shrubs have been reduced under pastoralism (**xS1yG**) and limited areas have been cleared for crops and native pastures. The present areas shown as **cwS2Z** east of the wheatbelt in WA and **xS2Z** on the islands off Tas. are the result of the modification of open scrubs by burning or grazing.



Mallee shrubland over low shrubs
A remnant patch of mallee eucalypt vegetation with a dense understorey of Melaleuca *low shrubs* (**eS2Z**). *This small area near Pingaring lies well within the WA wheatbelt.*

Scrub-heath near Hyden (WA)
This vegetation type is found on infertile sandy soils in inland south-western WA. In the natural stands of scrub-heath there is a range of shrubby genera (**xS2Z**), *including* Allocasuarina, Banksia, Hakea *and* Callitris *(pictured). Some areas of scrub-heath have been cleared in recent decades along the eastern margin of the wheatbelt.*

S2

Mallee over hummock grass
Ridge-fruited mallee (Eucalyptus incrassata) and Triodia species in the Hattah–Kulkyne National Park, north-western Vic. Hummock grass understoreys are common in mallee areas on sandplains and render such vegetation highly flammable.

Tall shrubland with hummock grasses S2H

Some of the mallee shrublands in southern Australia have an understorey of hummock grasses of the genus *Triodia* (**eS2H**). These are associated with calcareous or sandy soils. These soils may favour the growth of hummock grasses rather than low shrubs, but in addition the shrubs may be suppressed by fire. The highly flammable *Triodia irritans* is commonly found in these shrublands, particularly on light and sandy soils, and this species provides fuel for very intense fires (Noble and others 1980). Some former areas in the south-east have been cleared and sown to seasonal crops with native pastures.

Areas dominated by *Acacia* (**wS2H**, **weS2H**) occur across north-central and north-western Australia, largely on sandplains or dissected country. *A. aneura* is the most widespread species but *A. stipuligera* and *A. lysiphloia* are prominent in the north, as are *A. stowardii* and *A. shirleyi* in the east. The hummock grasses include *Triodia basedowii* and *T. pungens*. *A. aneura* and *T. basedowii* dominate a vegetation mosaic found on areas of dissected laterite plateau in the Gibson Desert. This mosaic, described by Beard (1968) as 'mulga parkland', is generalised as **ws2H**.

MALLEE

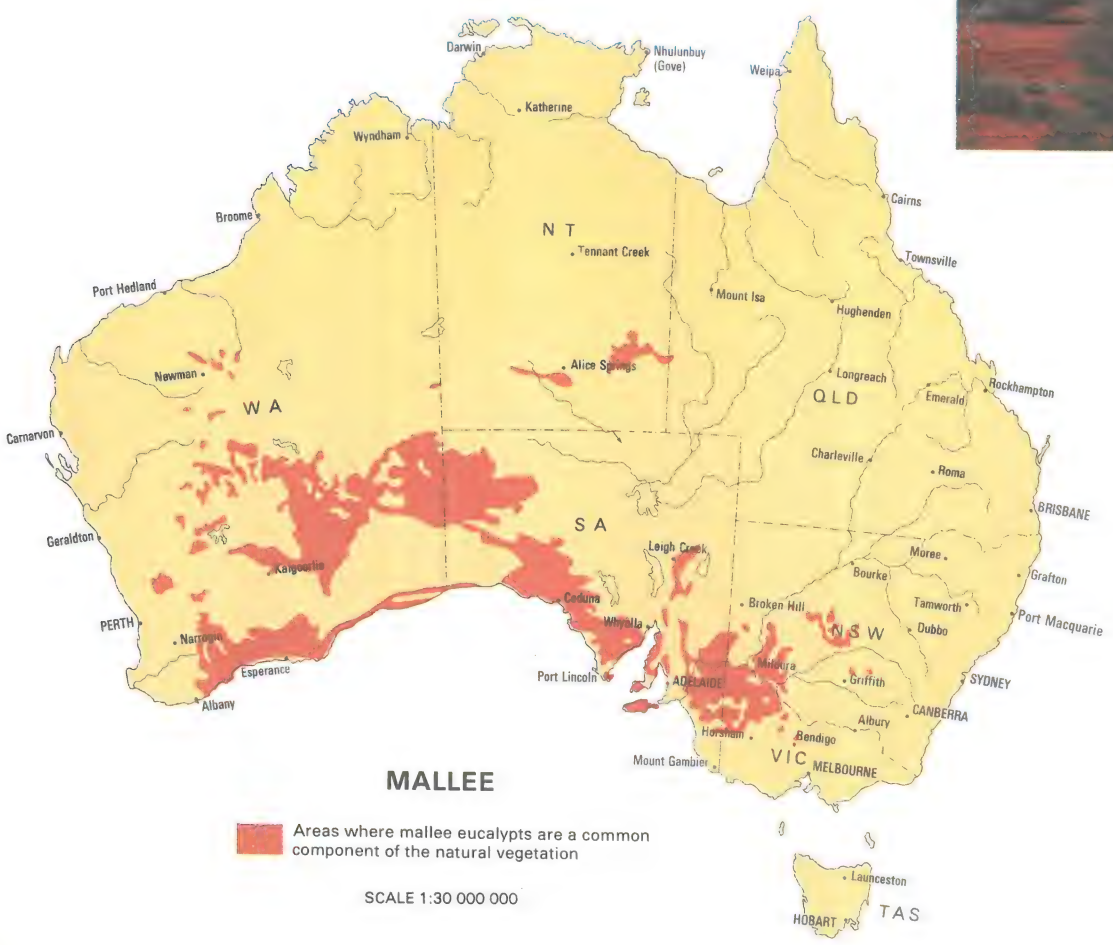
The term 'mallee' describes eucalypts with a multi-stemmed habit and the vegetation dominated by them. Mallee eucalypts have branches arising from an underground mass of woody stem tissue (lignotuber) and are structurally classed as tall shrubs.

Most mallee vegetation ranges from 3–9 m in height, although there are some exceptional stands over 10 m such as those of *E. diversifolia* on Kangaroo Island (SA). The number of branches varies from a few large stems in 'bull' or 'big mallee' (right), to the many narrow branches of 'whipstick mallee' (lower right). Mallees are fire tolerant and produce new shoots from the lignotuber after burning.

Many of the areas dominated by mallee shrublands occur across southern Australia on a range of calcareous soils within the 250–380 mm annual rainfall zone (Parsons 1981). Outside these core areas much mallee vegetation occurs as tall open shrubland, such as the mallee-heaths of southern coastal WA (**eS1xZ**) and the widespread arid mallees found on sandplains in the Great Victoria Desert and north of the Simpson Desert (**ewS1tH**).

There are over 100 mallee species of *Eucalyptus*. Most occur in WA, though some, such as *E. oleosa*, *E. gracilis*, *E. foecunda*, and *E. incrassata* are widespread in both the east and west of the continent. Some species may occur in either tree or shrub form. Mallee vegetation is also found on rocky soils in some mountainous areas in southern Australia.

The understorey varies with both soil and rainfall. Shrub understoreys range from dense thickets of *Melaleuca* or *Casuarina* in the 'broombush mallee' to the more widespread heath-like or xeromorphic low shrub layers. Infertile sandy soils in drier areas have a highly flammable *Triodia* hummock grass undestorey. The heavier soils of the arid zone typically have an understorey of sparse grasses or annuals, or of semi-succulent low shrubs including chenopods.



S2

Tall shrubland with tussock grasses S2G

Of the different vegetation types that are dominated by *Acacia aneura*, the most widely distributed is tall shrubland over tussock grasses (**wS2G**). There are many examples of this type in areas where annual rainfall is less than 250 mm. It is found on a range of soils including massive red earths, alluvium, shallow soils over rock or hardpan and also the interdune areas of some sand-dune country.

In some places *A. aneura* occurs in groves. The ground layer usually includes some perennial grasses, especially *Eragrostis* and *Danthonia*, and also a seasonally fluctuating grass and forb component including *Aristida* and *Enneapogon*, *Helipterum*, *Ptilotus*, *Sida* and *Sclerolaena*. *A. aneura* undergoes longer term fluctuations in cover in response to prolonged drought (Beard 1968). Other species of *Acacia* may be associated with *A. aneura*, including *A. brachystachya* in the south and *A. loderi* in the south-east.

As the map of Present Vegetation shows, large areas of this vegetation type (**wS2G**) have been modified under pastoralism and this is usually reflected in a reduction of the tallest stratum to **wS1yG**. The Fortescue Valley in the Pilbara region of WA now has a very sparse ground layer and the area is coded as **wS2**. Some former areas of **wS2Z** in the interior of WA have been modified to **wS2G** through the reduction of palatable low shrubs by grazing stock.

The Present Vegetation map also shows small areas of this subform in south-eastern Australia dominated by mallee species of *Eucalyptus* (**eS2G**, **eqS2G**). Some of these represent modifications of former tall shrubland with low shrubs, but others may be natural.

Tall shrubland with other herbaceous plants S2F

In WA the *Acacia* tall shrublands with low shrubs (**wS2Z**) are replaced along their south-western margin by another type in which the low shrub layer is less prominent and the ground cover consists of seasonal forbs (**wS2F**). There are numerous species of *Acacia*, including *A. ramulosa* and *A. linophylla* in the south and *A. xiphophylla* in the north. The seasonal ground layer consists largely of Asteraceae including species of *Helipterum*, *Myriocephalus* and *Podolepis*. Some areas of this type have been modified under grazing (**wS1zF**).

MULGA

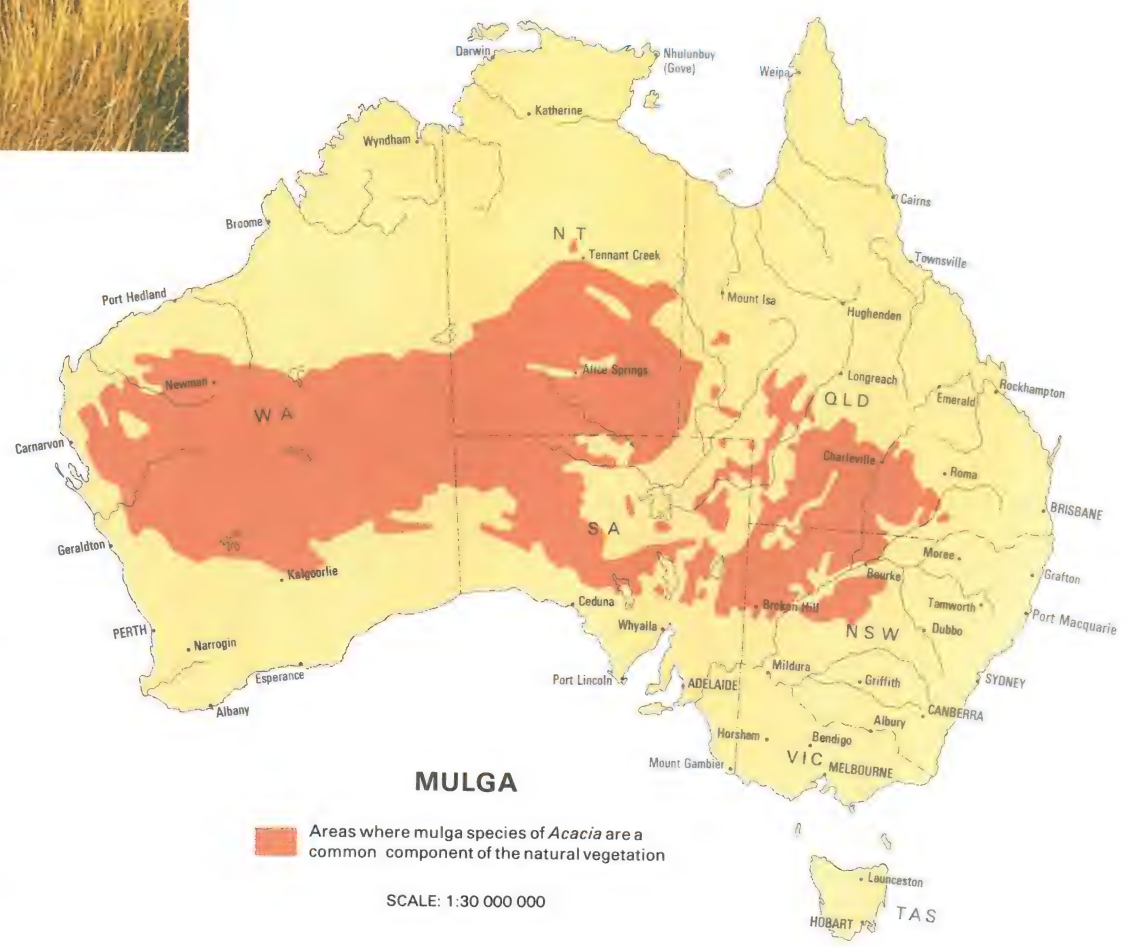
Mulga is a widespread and well known Australian vegetation type. The mulga lands occupy about 500 million ha, or about 20% of the continent. Mulga vegetation ranges in form from open forests up to 15 m high in Qld to sparse shrublands in desert areas, but occurs most commonly as tall shrubland or low woodland. The two photos show plains north of Alice Springs (NT) blanketed by mulga tall shrubland (**wS2G**).

The term mulga usually includes the widespread *Acacia aneura* (mulga) and the closely related species *A. linophylla* (bowgada), *A. brachystachya* (umbrella mulga) and *A. ramulosa* (horse mulga), also *A. stowardii* (bastard mulga). The 'Mulga' map shows the areas where these species are a dominant or a common component of the natural vegetation (see also the Acacias map on page 15).

Most of the mulga lands are used for livestock grazing. Mulga foliage is an important source of drought relief fodder. Graziers in eastern Australia have felled mulga for fodder or to increase pasture growth. Dense regeneration occurs in some areas, notably in the 'soft mulga' lands of south-western Qld, but in drier areas mulga does not regenerate to its former density.

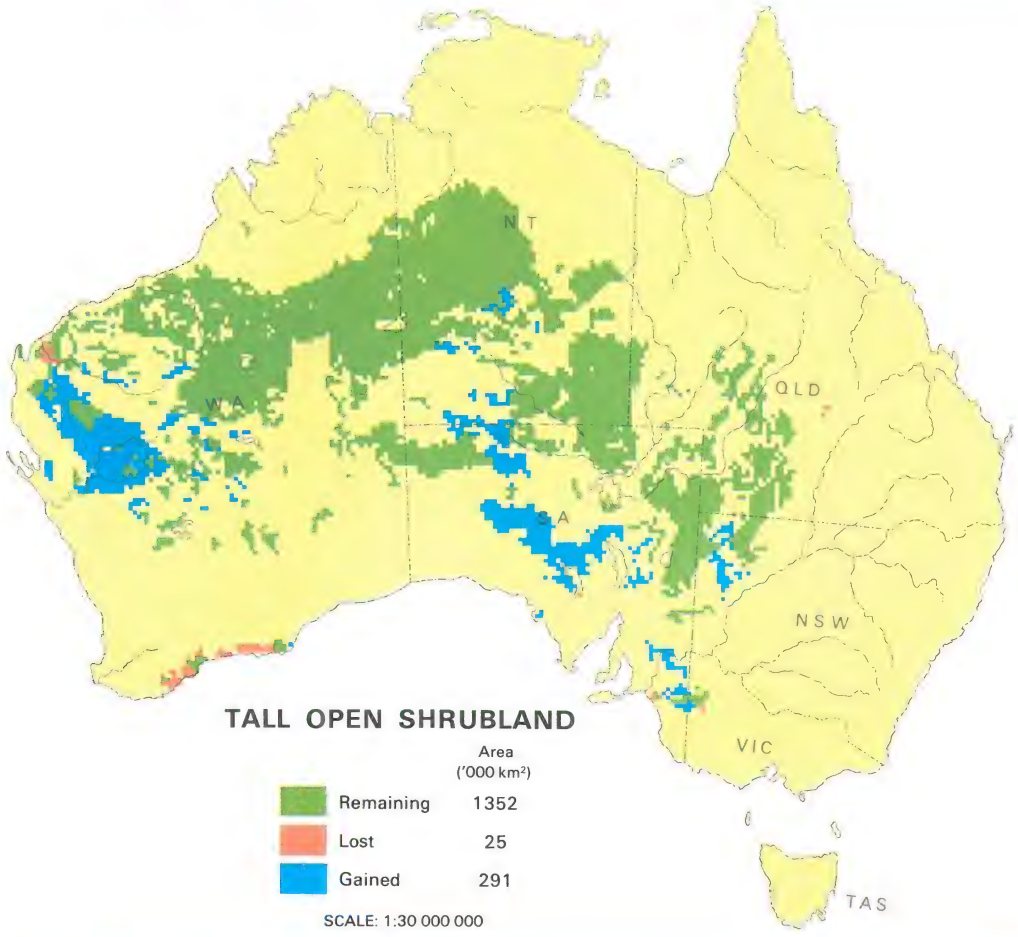
In many parts of Australia, grazing the mulga lands has resulted in the reduction of the dominants, the low shrubs, or the ground plants, or even of all three layers. These changes in the vegetation are often accompanied by soil erosion. Assessing the effects of the grazing animals, and of rabbits, is complicated by the fact that mulga undergoes a cyclic pattern of decline and regeneration in response to prolonged drought. Much of the degradation of mulga lands took place from the 1880s to the 1930s.

In some grazed areas a dense layer of inedible low shrubs has appeared. The increase in these 'woody weeds' is particularly severe north and west of Bourke and Cobar in western NSW, and has significantly reduced the carrying capacity of these areas.



Tall open shrubland

Shrubs >2 m high; <10% foliage cover **S1**



Tall open shrubland is the single most widespread structural form of vegetation in Australia, covering more than 20% of the continent. Its area has actually increased slightly in historical times through reduction in the cover of denser shrublands.

The largest areas are found in desert sand country. There are many species of *Acacia* in the shrub layer, accompanied by other shrubs, mallees and scattered low trees. Tall open shrubland with a grassy or depleted understorey largely lies within the range of mulga, *Acacia aneura*.

Understorey types range from low shrubs to grasses and other herbaceous plants, or may be largely absent. Where the upper stratum is very sparse, this formation could perhaps be better described as scattered tall shrubs with the understorey as the characteristic feature of the vegetation.

Mallee-heath in the Stirling Range (WA)
*Eucalyptus tetragona or 'Tallerack' is a prominent mallee species along the WA coastline from Albany to Cape Arid, where it forms a tall open shrubland over a dense and diverse heath understorey (**eS1xZ**). This vegetation type also occurs at the same latitude in the Big Desert of western Vic., where E. incrassata is a prominent species.*

***Acacia* tall open shrubland over bluebush**
Across the southern inland this widespread vegetation type includes a number of Acacia *species. The photo shows western myall (*A. papyrocarpa*) over low shrubs of pearl bluebush (*Maireana sedifolia*) near Rawlinna, on the western margin of the Nullarbor Plain. Western myall also occurs as a low tree.*

Tall open shrubland with low shrubs S1Z

The 'mallee-heath' type (**eS1xZ**), dominated by species of *Eucalyptus*, occurs on sandy soils in the Big Desert area of western Vic. and SA, and on the south coast of WA. *E. incrassata* is widespread in this vegetation with *E. tetragona* prominent in the west. There is a dense sclerophyllous understorey including species of Proteaceae and Myrtaceae.

Some areas of former mallee-heath have been cleared for seasonal crops or pastures, dependent on massive applications of fertiliser to overcome the infertility of the soil. Some present areas of **eS1xZ** in SA are modified shrubland and contain many remnants of the former mallee vegetation (**eS2Z**).

Acacia tall open shrublands with a low shrub understorey of Chenopodiaceae (**wS1kZ**) are common in the present vegetation across the southern interior of Australia. This type is more restricted on the Natural Vegetation map because many of the present-day occurrences are the result of a decline in cover of former tall shrublands (**wS2Z**).

A. aneura is the most widespread species of *Acacia*, but others such as *A. linophylla* and *A. brachystachya* are also present. Some eastern areas are dominated by a wider range of genera (**xS1kZ**). The low shrubs include species of *Atriplex* and *Maireana*, together with more succulent types ('samphires', including *Halosarcia* and *Sclerostegia*) on the more saline soils.

Within the limits of the *Acacia* shrublands in WA, some rough stony areas carry open shrublands (**wS1xZ**) which are a depauperate extension of the **wS2Z** type. In north-western NSW the present area coded as **wS1xZ** reflects the development of a dense stratum of low shrubs which, under pastoral land use, has replaced the former grassy understorey (Booth and Barker 1981).

Over large areas of *Acacia* tall shrubland and some tall open shrubland (**wS2Z**, **wS1xZ**) in WA the cover in all strata has been reduced by grazing. These modified areas are shown on the Present Vegetation map as **wS1**.

Tall open shrubland with hummock grasses S1H

Acacias and mallee eucalypts are again the most frequent upper stratum dominants, although there are examples with *Hakea* (**hS1tH**) or various genera (**xS1tH**) dominant. This subform corresponds to the 'shrub steppe' of Beard (1967), with a uniform and conspicuous hummock grass layer beneath scattered tall shrubs.

Eucalyptus shrub steppe (**eS1tH**, **ewS1tH**) occurs throughout the central and western interior of Australia, associated with the sandplains and some interdune areas. The mallee species include *E. gamophylla* and *E. pachyphylla* in the north, *E. oleosa* and *E. youngiana* in the south and *E. kingsmillii* in the west. The mapped coastal outlier on the Cape Range in WA is dominated by a mallee form of *E. dichromophloia*. Species of *Acacia*, especially *A. aneura*, are prominent in some places (**ewS1tH**) and *Triodia basedowii*, with some *T. pungens*, is the principal hummock grass.

Acacia tall open shrubland with hummock grasses (**wS1tH**) is the characteristic vegetation of large areas of sandplain, especially in the NT, and of the sandridge country in and around the Simpson and Great Sandy deserts. This type usually occurs within the 100–300 mm annual rainfall range. Examples are also found on other kinds of terrain, including desert laterite and the granitic plains and rough basaltic country of the Hamersley Range region of WA.

Acacia, represented by many species, is usually regarded as the typical genus. The tallest stratum, however, often includes a range of genera, such as mallee eucalypts and species of *Hakea* and *Grevillea*, which in places may be co-dominant with *Acacia* (e.g. **weS1tH**, **whS1tH**, **xS1tH**). Some species,

including *A. aneura*, *A. dictyophleba* and *A. ligulata*, are widely distributed; others, including *A. stipuligera* in the north, *A. pachycarpa* in the north-western deserts and *A. pyrifolia* in the Hamersley Range region, have a more regional distribution.

Although the hummock grass layer is conspicuous, the plants are well spaced and the overall cover is relatively sparse. In places their density varies with drought or fire. The predominant species of *Triodia* are *T. pungens* in the north and *T. basedowii* in the south, although their ranges overlap. *Plectrachne schinzii* is a common associate of these species except in the south-east. Some areas of this vegetation are grazed and frequently burnt to induce palatable growth on the hummock grasses. There is also some herbaceous feed available between the hummocks.

Most of the mapped areas are either unsuitable for domestic stock grazing, and remain vacant, or are devoted to other purposes. Large areas of the sandplains and dunefields lie within desert nature conservation reserves, or are Aboriginal lands where limited hunting and gathering remains the principal land use. It is evident from satellite imagery that fires are widespread in these areas, arising from lightning, European activities or Aboriginal burning practices.

Mulga and mallee open shrubland on sandplain
Tall open shrubland over hummock grasses covers vast areas of arid Australia. Acacia aneura *and* Eucalyptus kingsmillii *form an association on the sandplains to the east of Wiluna in WA (pictured). The hummock grass is* Triodia basedowii.

Tall open shrubland with tussock grasses S1G

Examples are scattered across Australia throughout the lower rainfall areas. *Acacia* is the most frequent dominant (**wS1yG**), sometimes associated with other genera (**whS1yG**, **xS1yG**). A few modified examples are dominated by mallee eucalypts (**eS1yG**).

This subform is more prominent on the Present Vegetation map because many of the examples result from changes to denser shrublands. Many areas that are coded as **wS1yG** reflect a reduction of the tallest stratum of former *Acacia* shrublands (**wS2G**). In SA present areas of **eS1yG** are a generalisation of remnant patches of degraded mallee within the wider landscape of seasonal crops and pastures; similarly, **xS1yG** results from the modification of former **xS2Z** or **xS1kZ**. The induced native pastures include species of *Stipa* and *Danthonia*. A small area mapped as **xS1yG** south of Darwin represents regrowth on formerly cropped land that was cleared from *Eucalyptus* woodlands (**eM2G**, **eL2G**).

Natural examples with *Acacia* dominant may be regarded as an extension of the grassy *Acacia* tall shrublands (**wS2G**) into drier areas (<100 mm annual rainfall) or on to poorer soils. One distinct environment is provided by the clayey soils of the interdune areas in the south-eastern Simpson Desert, where the species include *A. georginae*, *A. victoriae* and *A. tetragonophylla* (**wS1yG**).

There is a wide range of dominant species, some of which, including *Acacia aneura*, *A. victoriae* and *A. ligulata*, are widely distributed. Others, such as *A. kempeana* and *A. georginae* in central Australia, have a more regional distribution. The latter occurs on heavy soils to the north of the Simpson Desert, and on the clay interdunes on its eastern edge. Characteristic species of other genera include *Hakea leucoptera* (**whS1yG**), and the tussock grasses include *Aristida*, *Eragrostis* and *Enneapogon*. The ground layer, which fluctuates greatly with seasonal conditions, also contains a considerable forb component, including species of *Ptilotus* and *Sclerolaena* and members of the Asteraceae.

While most of the natural examples of mixed tall open shrubland (**xS1yG**) are similar to those dominated by *Acacia*, there are some limited but distinctive types such as that mapped on small areas of alkaline clays north of Charleville in central Qld (**xS1aG**). The dominant species include *Albizia basaltica*, *Lysiphyllum carronii* and *Ventilago viminalis*, with a ground layer of *Astrebla*.

Some former areas of **wS1yG** have been modified by the reduction of the tallest stratum, as in the lower Ashburton Valley in north-western WA (to **yG3**). In north-western NSW the replacement of the grassy understorey by dense low shrubs is discussed under **wS1xZ** above.

Open shrubland of the Simpson Desert
The linear sand dunes of the Australian desert country slice across the plains and form a vast mosaic of different dune crest and corridor vegetation. In these areas the map codes apply to the more extensive corridoors and are underlined to indicate the presence of a separate sandridge vegetation (e.g. **wS1tH***). The Simpson Desert provides some of the most striking examples of this striped mosaic, as can be seen in these two photos. The interdunes and stable lower dune slopes carry open shrublands with a tussock or hummock grass understorey whereas unstable dune crests have a very sparse and distinctive flora including* Zygochloa paradoxa*, the sandhill canegrass (foreground).*

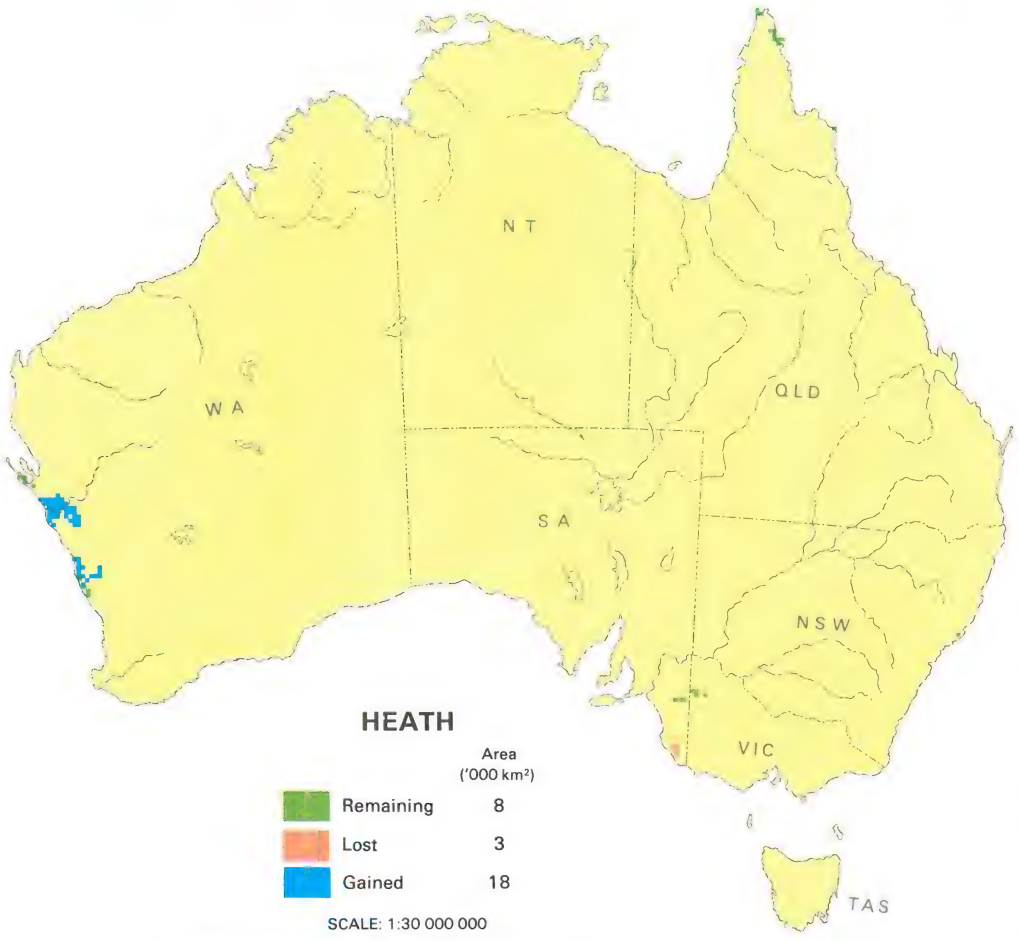
Tall open shrubland with other herbaceous plants S1F

In SA some former areas of *Eucalyptus* tall shrubland or tall open shrubland, with low shrubs (**eS2Z**, **eS1xZ**) have been partially cleared and sown to seasonal crops in association with pastures (**eS1yfF**, **eS1*yfF***). The perennial sward-forming grasses include *Phalaris aquatica* and *Dactylis glomerata*; the seasonal grasses include *Lolium rigidum*. The main legumes are the seasonal *Trifolium subterraneum* and *Medicago* species, but there is also some perennial *Medicago sativa*. In western WA, part of the *Acacia* tall shrubland with a seasonal ground layer of Asteraceae (**wS2*F***) has been reduced under pastoralism to **wS1*zF***.

Degraded mulga country in WA
Parts of the mulga in several states have suffered a decline in shrub density and ground cover as a result of pastoral land use. At their western edge, former Acacia *shrublands with a low shrub understorey over grasses and forbs have lost much of both their shrub and ground layers and are now coded as* **wS1**.

Low shrubs

Open heath — Shrubs <2 m high; 30–70% foliage cover — Z3



The term 'heath' originates from Europe where it described members of the plant family Ericaceae and the low shrub communities dominated by its members. Australian heathlands are structurally similar but while members of the southern hemisphere equivalent of this family—the Epacridaceae—are common, several other families are also prominent.

Closed heath (**Z4**) usually occurs as denser patches within open heath (**Z3**) formations and is not mapped separately. Although the total mapped area of heathland is limited, it is a widespread formation of many coastal and alpine areas. The largest areas of open heath are in south-western WA, east of Adelaide and along the east coast from Cape York to Tas.

Heaths are a floristically very rich formation of diverse shrubby genera. There may be a ground layer of graminoids and forbs. In WA the heath flora contains about 2000 species and a number of endemic genera. Heaths are also an important fire-adapted habitat for a variety of native fauna.

Open heath is often a component of a mosaic with related vegetation types such as closed heath, scrub-heath, scrub and sedgeland. Soil and water-table depth are important factors in limiting the development of taller vegetation, but frequent burning also plays a role in maintaining the open heath structure.

Heaths have a patchy distribution in coastal or near-coastal situations throughout Australia under annual rainfalls ranging from more than 1600 mm (e.g. near Cape York) to less than 300 mm. They grow on a wide range of soil types, all deficient in essential plant nutrients such as nitrogen and phosphorus.

The floristic composition of open heaths varies with soil type, but there are usually many species from a number of families including Proteaceae, Myrtaceae, Fabaceae and Epacridaceae (**xZ3**). The mapped examples east of Adelaide are dominated by *Banksia ornata*, *B. marginata* and *Allocasuarina pusilla* (**bcZ3**). In the temperate examples many of the shrubs are ericoid, but there is a tendency towards broader leaves in the tropical areas. Species of *Xanthorrhoea* are often present. There may be a ground layer of graminoids, especially Cyperaceae and Restionaceae, together with some forbs (**xZ3G**).

It is often difficult to separate open heath from scrub-heath (**xS2Z**), since the predominance of either form in some areas depends on the frequency of fires. Large areas in WA shown as scrub-heath on the Natural Vegetation map are now generally kept in the open heath condition (**xZ3**) by frequent burning.

Some former areas of open heath in Tas. and SA have been replaced by sown exotic pastures; large applications of fertiliser are needed to maintain the new vegetation.

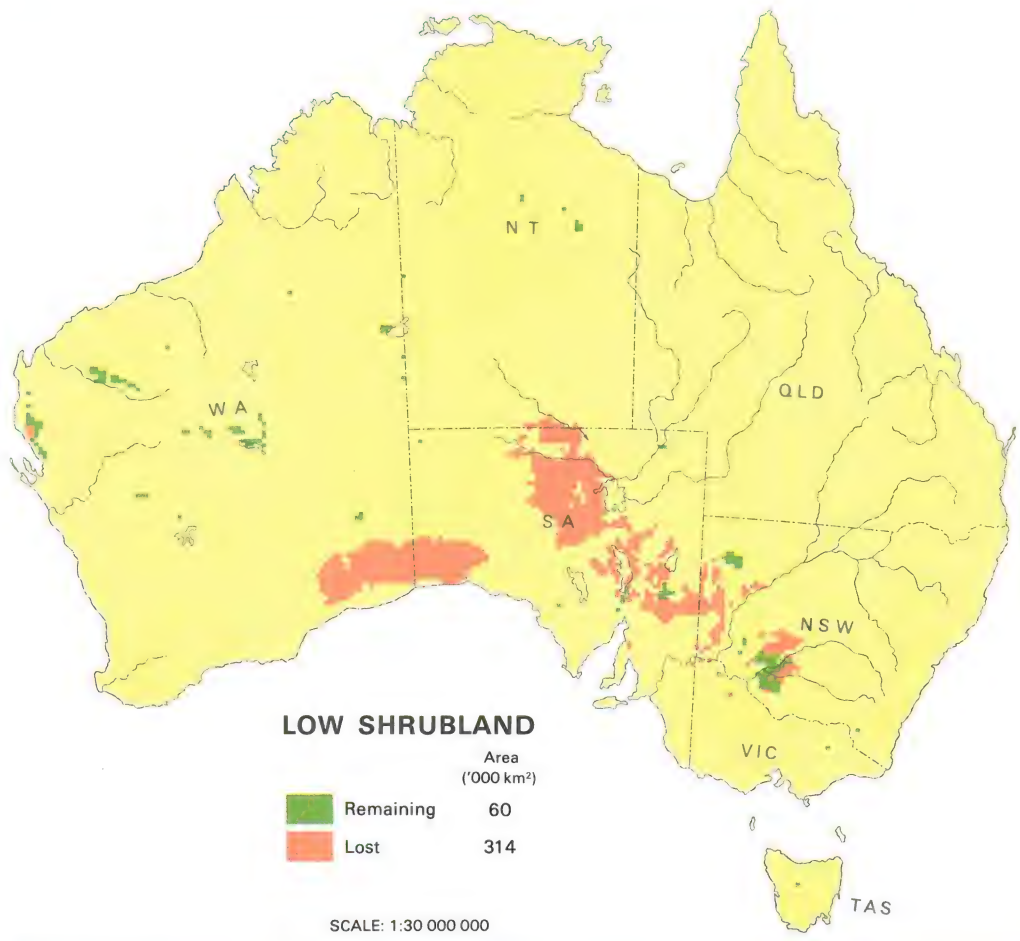
Heath on sand dunes, Cape York Peninsula
The largest mapped area of heath in eastern Australia extends from the sand dunes at Shelburne Bay (above) to the centre of northern Cape York Peninsula.

Springtime in the heaths of WA
It is the heathlands of the south-west which truly make WA the 'Wildflower State'. There are about 2000 plant species and many endemic genera in the WA heath flora. These two photos (right) show the variation in species composition found at different locations along the west coast.

Low shrubland

Shrubs <2 m high; 10–30% foliage cover **Z2**

Low shrublands formerly covered about 5% of Australia. The major part of this area is still dominated by saltbush and bluebush, but shrub density and foliage cover has declined as a result of grazing. Saltbush country has been important to the wool industry for well over a century and is still primarily devoted to sheep grazing. Although highly variable in structure, the treeless alpine vegetation of south-eastern Australia and Tas. has also been coded as low shrubland.



Low shrubland with tussock grasses and graminoids Z2G

The extent of the grassy low shrublands of Chenopodiaceae (**k22G**) is much reduced on the Present Vegetation map, though they still occupy parts of the large areas now generalised as **kZ1yG**. They occur mainly on calcareous or saline soils across southern Australia, generally within the 100–350 mm annual rainfall range.

The principal genera are *Atriplex*, including the taxonomic complexes currently classified as *A. vesicaria* and *A. nummularia*; and *Maireana*, including *M. sedifolia*, *M. astrotricha* and *M. pyramidata*. The local predominance of these widespread species is related to the physical and chemical characteristics of the soil. More succulent chenopod shrubs ('samphires', including species of *Halosarcia* and *Sclerostegia*) may also be present in low-lying saline areas. *Chenopodium auricomum* occurs in some areas mapped as **kZ2G** on heavy clay soils south and east of Newcastle Waters in the NT.

The herbacaous stratum includes perennial grasses such as *Eragrostis*, *Danthonia* and *Stipa* on heavy soils. Species of *Astrebla* are also present on such soils in the north. On lighter and more elevated soils there is a seasonally fluctuating ground layer of grasses such as *Stipa* and *Enneapogon*, and also forbs, especially species of *Sclerolaena* and of Asteraceae.

Most of these low shrublands have been grazed by sheep in the south and cattle in the north. While the dominant shrubs can withstand some grazing, at least in the higher-rainfall areas, the shrub layer has generally been reduced under pastoralism (e.g. to **kZ1yG**, **kZ1xF**, or even **yG2**). On the Nullarbor Plain, which is largely ungrazed because of the lack of water, this reduction has been attributed to the combined effects of rabbits, fire and drought (Mitchell and others 1979). However, it is difficult to separate the relative roles of these factors, both on the Nullarbor Plain and in pastoral areas.

There are a few mapped examples with a floristically diverse shrub stratum (**xZ2G**). The most distinctive are those found above the treeline in alpine areas. The treeline reaches a maximum altitude of about 1800 m in the Snowy Mountains and the Victorian alpine areas, and about 1350 m in Tas., but it is obscured by the effects of cold air drainage. The treeless areas carry a mosaic of shrubby and herbaceous vegetation which is generalised as low shrubland with tussock grasses and graminoids (**xZ2G**).

The shrub layer contains species from many families, including Epacridaceae, Myrtaceae and Proteaceae. The herbaceous layer includes tussock grasses of the genus *Poa* and forbs of the family Asteraceae. Cyperaceae, including species of *Carex*, are prominent on the wetter soils. In the past, grazing caused some changes to this vegetation. Large areas are now within national parks but are subject to the effects of recreational activities.

Two small areas are mapped as **xZ2G** in the western interior of Australia. One is on lake flats in the Tanami Desert, with chenopods and other low shrubs; the other is on a sandplain in north-western SA. On Rottnest Island, near Perth, the natural vegetation of *Callitris preissii* (**pL4**) has been reduced by clearing, burning and browsing by wallabies to a grassy low shrubland dominated by the semi-succulent *Acanthocarpus preissii*, with *Stipa variabilis* prominent in the ground layer (**xZ2G**).

Low shrubland with other herbaceous plants Z2F

Saline coastal flats to the north and south of Carnarvon (WA) carry low chenopod shrublands, with species of *Atriplex*, *Maireana* and *Halosarcia* and a distinctive ground layer of seasonal forbs, including Asteraceae (**kZ2F**). Part of this area is now coded as **kZ1zF**, while further south the decline of *Acacia* tall shrubland (**wS2Z**) has extended the area of **kZ2F**.

The same code (**kZ2F**) has been used on the Natural Vegetation map for a similar low shrubland on saline duplex soils north of Port Augusta (SA). This area is now occupied by more open vegetation (**kZ1xF**). It may previously have had a more perennial forb element, as exists in the present vegetation of the area mapped as **kZ2F** in north-western Vic.

Alpine vegetation on the NSW Snowy Mountains
Diverse mixtures of low shrubs, including the dwarf conifer Podocarpus lawrencii, *with tussock grasses and forbs (above) are a major part of this mosaic coded as* **xZ2G**.

Cushion plants and tussock grass, Heard Island
The vegetation of Macquarie and Heard islands in the Southern Ocean is similar to the herbaceous component of the Australian alpine vegetation. The photo shows Poa *tussocks,* Pringlea, *and the cuhion plant* Azorella selago, *which is common to both islands. The vegetation of Macquarie Island has been modified by introduced rabbits.*

Saltmarsh near Port Augusta (SA)
Low shrubland of samphires (Halosarcia *and* Sclerostegia) *on a salt flat at the head of the Spencer Gulf. Similar vegetation grows on the margins and beds of inland salt lakes.*

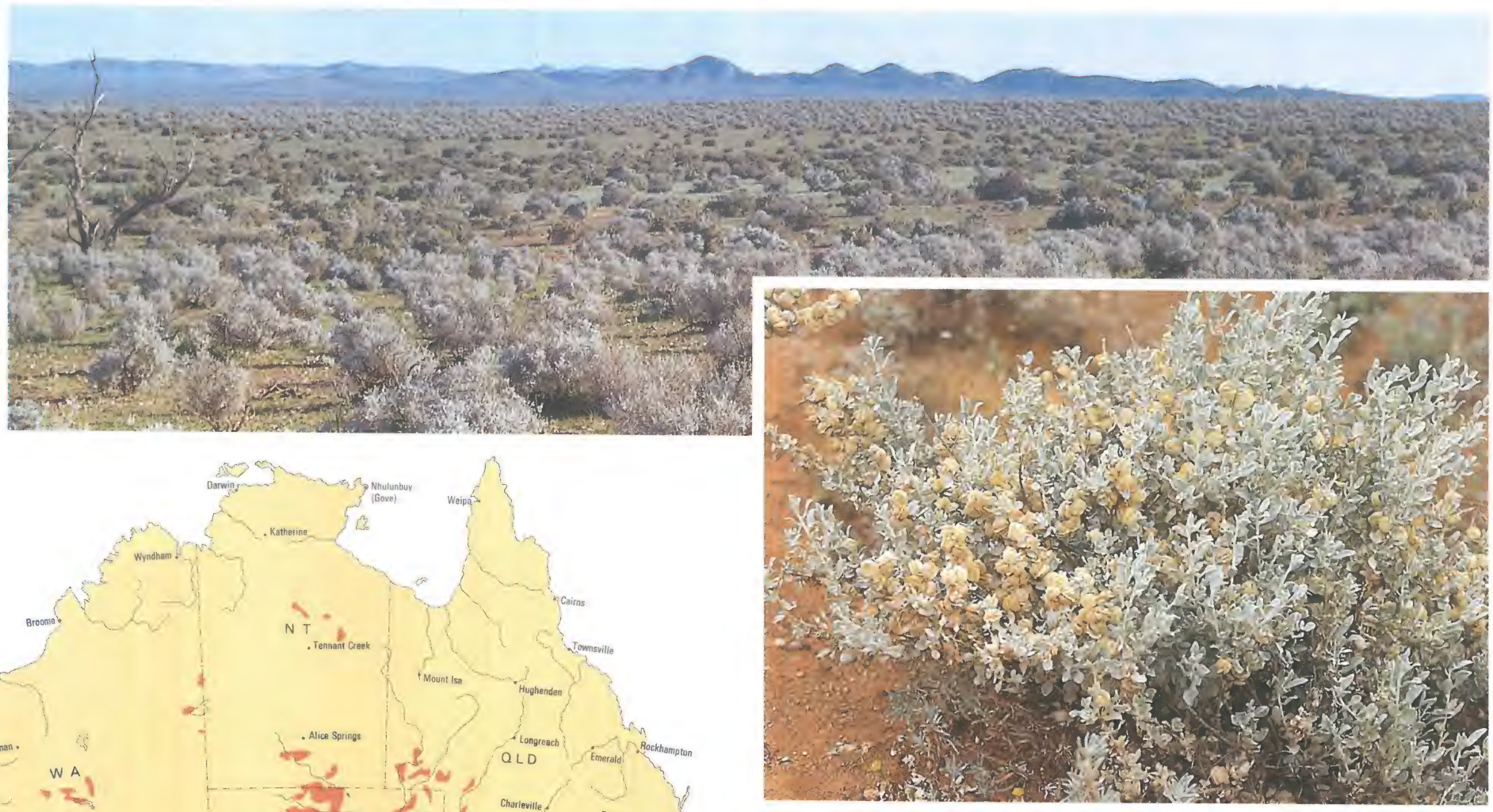
Low shrubland with no significant lower stratum Z2

This subform is dominated mostly by succulent species of Chenopodiaceae (samphires). The total area of **kZ2** is small, despite examples being widespread on highly saline soils in low-lying coastal areas (where they are largely included in the 'littoral complex') and the arid interior. The principal genera include *Halosarcia* and *Sclerostegia*, which occur as dwarf shrubs generally less than 1 m in height. The ground between these shrubs is usually quite bare. On higher ground the shrub layer may also include species of *Atriplex* and *Maireana*, together with non-chenopods of similar form such as species of *Frankenia*.

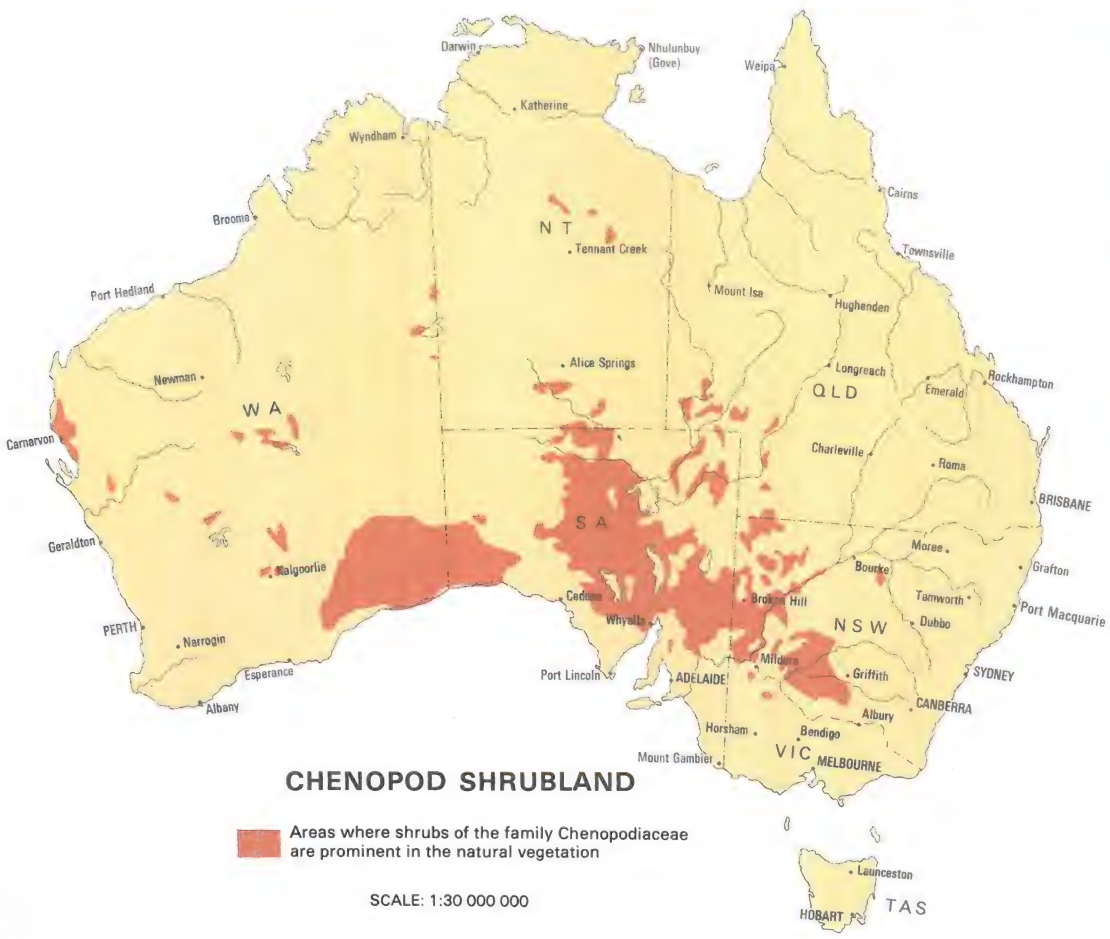
The area occupied by this type is increasing under settlement, as the rising of saline water-tables in agricultural regions causes land salinisation (Woods 1983). However, most of the acutely affected sites are too small to map at 1:5 million scale.

The examples mapped as **xZ2** represent a range of vegetation types. Some areas of low shale hills to the south of the Hamersley Range (WA) carry low shrubs, notably *Eremophila* and *Cassia*, with only very sparse seasonal forbs and grasses. Goyder Lagoon, on the Diamantina floodplain in north-eastern SA, is occupied by a low shrubland of *Muehlenbeckia cunninghamii*. St. Peter Island in the Great Australian Bight also carries sparse low shrubs.

SALTBUSH, BLUEBUSH AND SAMPHIRES



Saltbush and bluebush plains in SA
Saltbush and bluebush occur across southern Australia from the western edge of the Nullarbor Plain in WA to the eastern part of the Riverine Plain in southern NSW. They occur on calcareous soils or, as the name suggests, on saline soils. In SA they extend north on the western side of Lake Eyre and into the NT, mainly on red duplex soils.



Plants from several genera of the family Chenopodiaceae dominate this vegetation. Species of *Atriplex* (saltbush) and *Maireana* (bluebush) are the most prominent, while *Chenopodium* may dominate in flood-prone situations. One of the most widespread and economically important species is *Atriplex vesicaria*, the bladder saltbush (above), found from WA to NSW. The samphires occur in low-lying saline areas such as dry lake beds.

The structure of the treeless chenopod shrubland has been described as 'steppe' because of its low stature (generally <1.5 m) and uniformity but one species—*Atriplex nummularia*, the 'old man saltbush'—may attain a height of 3 m. Chenopod shrubs also form the understorey for low woodlands and tall shrublands of *Acacia* and *Casuarina* over extensive areas of southern Australia.

On the Present Vegetation map the coding of large tracts of chenopod shrubland has been changed from **kZ2G** to **kZ1yG**, indicating a general reduction in shrub density and cover. Although saltbush recovers well after drought, there is evidence that the population numbers are reduced by continuous grazing. The trend in pastoral country has been toward a decrease in perennial vegetation. This has been demonstrated for several chenopod shrubs, including *Maireana sedifolia* and *Atriplex vesicaria*. Over the eastern part of the Riverine Plain in NSW, the former *Acacia pendula* woodland with an *Atriplex nummularia* understorey has been largely replaced by short grasses as a result of clearing and grazing.

Low open shrubland

Shrubs <2 m high; <10% foliage cover **Z1**

Many of the natural occurrences of this formation are found in the arid interior of Australia. Here, some low open shrublands occur in extreme environments such as rocky ranges or the skeletal soils of erosional landscapes.

Low open shrubland with hummock grasses Z1H

The few mapped areas are generally dominated by species of *Acacia* (**wZ1tH**) and, except for one example on the Qld–SA border, are confined to coastal areas in north-western WA. There is a range of species, *Acacia tetragonophylla* being a fairly widespread example. The principal hummock grasses are *Triodia pungens* and *T. basedowii*. In one area *Acacia* is co-dominant with other genera (**xZ1tH**).

Low open shrubland with tussock grasses Z1G

Most of the present chenopod low open shrubland (**kZ1yG**) in southern Australia results from the general decline in plant numbers and cover in former low shrubland (**kZ2G**). Certain species have tended to increase in these modified shrublands, such as *Maireana aphylla* and the non-chenopod *Nitraria billardieri*. There have also been changes in the herbaceous layer, such as the widespread appearance of the seasonal exotic volunteer forb *Carrichtera annua*.

Some other present areas of this type reflect the removal of a former taller overstorey, such as *Acacia pendula*. There are also natural examples of **kZ1yG** in low rainfall areas or on poor soils. Some of these have also been modified under pastoralism (to **yG2** or **kF1**).

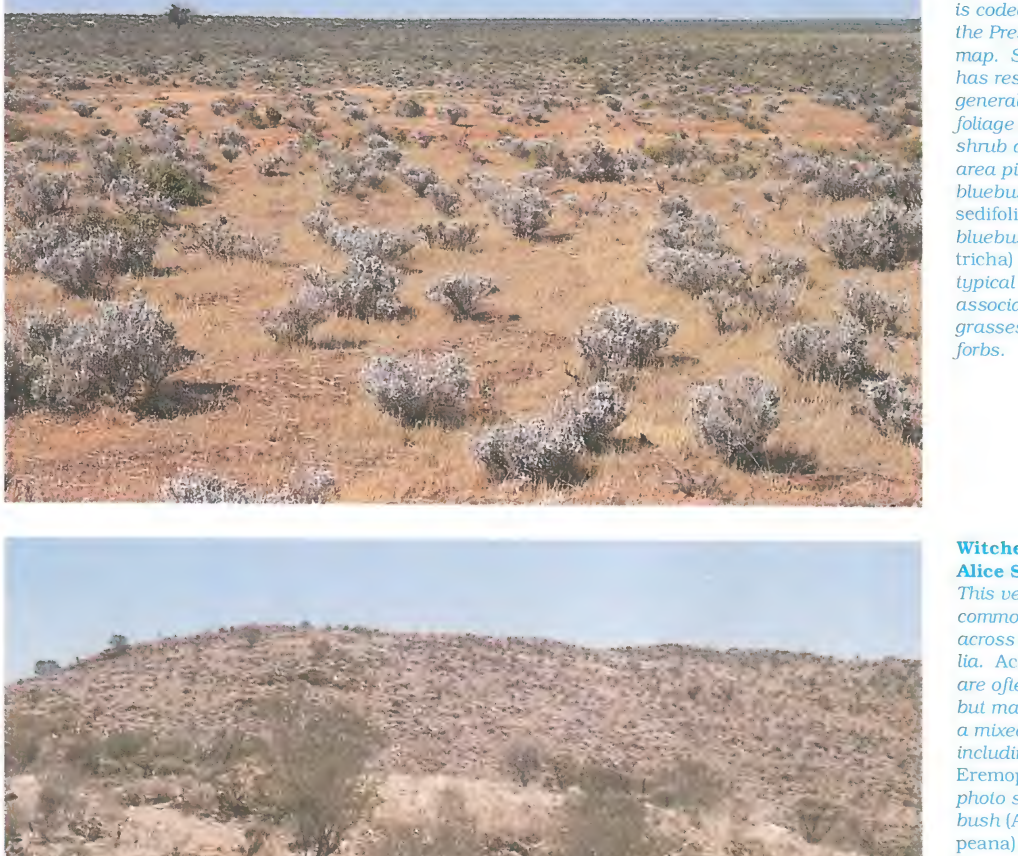
Examples of this subform in the interior of Australia are found on shallow soils on terrain that ranges from plains to rugged hills. *Acacia* species, especially *A. kempeana* (**wZ1yG**), are frequent dominants, though in some areas several genera including *Acacia*, *Cassia* and *Eremophila* are present (**xZ1yG**). The tussock grasses include *Aristida* and *Enneapogon*, with *Astrebla* on some heavier soils. The ground layer usually also contains forbs, such as *Helipterum* and *Ptilotus*.

Low open shrubland with other herbaceous plants Z1F

Although some examples on the Present Vegetation map (**kZ1xF**, **kZ1zF**) result from historical changes, those in arid south-western Qld and north-eastern SA are natural. They occur on clay plains between dunes and the dominant low shrubs include *Atriplex nummularia* and *Chenopodium auricomum*. Herbaceous species of *Atriplex* and *Sclerolaena* (**kZ1kF**) or a wider range of forbs (**kZ1xF**) usually dominate the ground layer. This is a generalisation of the average cover and composition of vegetation that fluctuates greatly with seasonal conditions, including occasional flooding.

Low open shrubland with no significant lower stratum Z1

Several areas of stony plains and tablelands in south-western Qld are occupied by low open shrublands of *Acacia stowardii* (**wZ1**), with an extremely sparse ground cover of tussock grasses and forbs. There is also very sparse vegetation (**kZ1**) on Lake Woods, south of Newcastle Waters (NT) and on salt flats in central Australia.



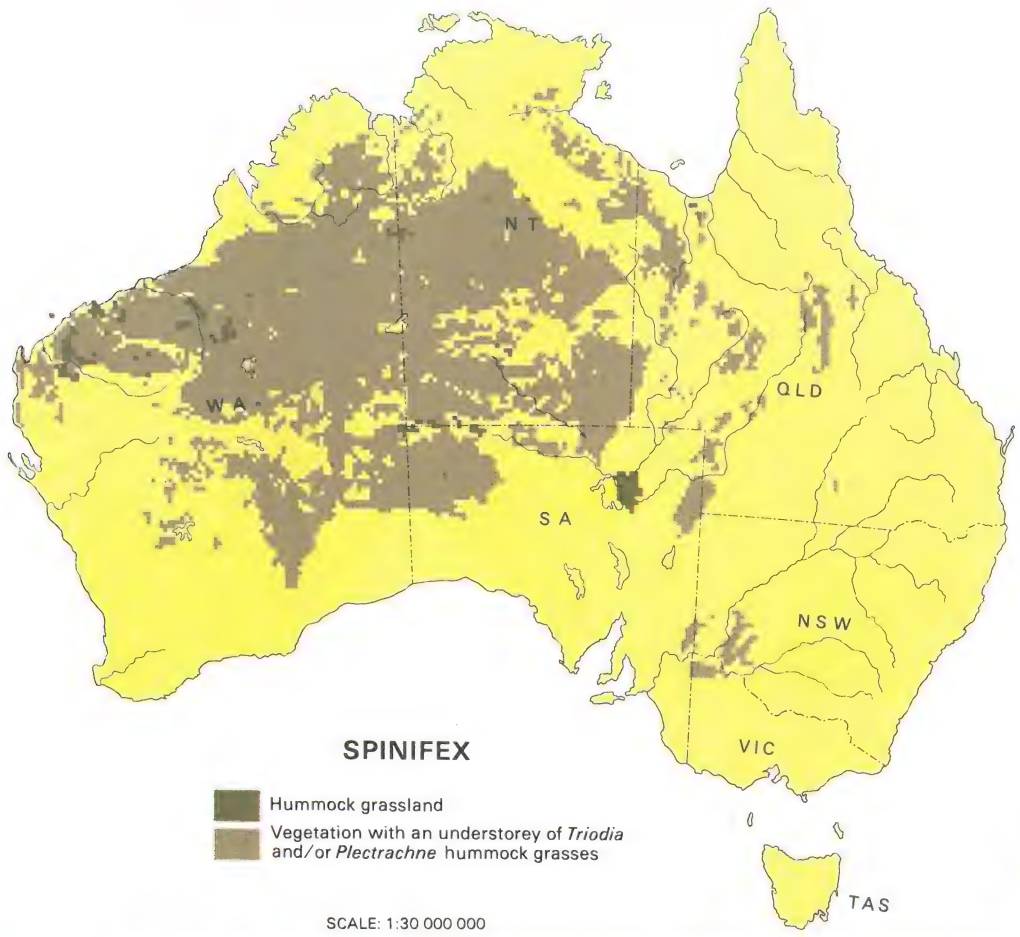
Bluebush low open shrubland near Renmark (SA)
Most of the saltbush and bluebush country of southern Australia is coded as **kZ1yG** *on the Present Vegetation map. Sheep grazing has resulted in a general decline in foliage cover and shrub density. In the area pictured pearl bluebush* (Maireana sedifolia) *and low bluebush* (M. astrotricha) *occur over a typical disclimax association of sparse grasses and chenopod forbs.*

Witchetty bush near Alice Springs
This vegetation type is common on rocky hills across central Australia. Acacia *species are often dominant, but many areas have a mixed shrub cover including* Cassia *and* Eremophila. *This photo shows witchetty bush* (Acacia kempeana) *and* Cassia *species over sparse tussock grasses.*

Low open shrubland near Lake Eyre
On the wide stony plains along the western side of Lake Eyre the only vegetation cover is a Chenopod low open shrubland (far left). Saltbushes are the principal shrubs but on saline areas bordering the salt lakes dwarf samphires are often dominant.

Grasses and graminoids

Hummock grasses H



The evenly spaced mounds of spinifex so typical of Australia's desert country are usually quite spiny at close quarters. These hummock grasses are in fact members of the genera *Triodia* and *Plectrachne*, found only in Australia.

While hummock grasslands without an overstorey of woody vegetation (**H2**) are quite restricted, other forms of vegetation with a hummock grass understorey cover about 25% of the continent. The most widespread mapped examples are **L1H** and **S1H**, where the hummock grasses may be more conspicuous than the scattered shrubs and low trees. They are also a frequent understorey in inland woodlands and shrublands. The 'Spinifex' map includes those formations with a hummock grass understorey.

Hummock grass understoreys occur as far north as the Kimberley region (WA) and Arnhem Land (NT). In Qld they occur as far east as Jericho; in the south they extend from WA to north-western Vic. The actual distribution of the hummock grass genera extends beyond their mapped occurrences as '**H**'.

Of all Australian vegetation types, those with hummock grasses dominant in the ground layer are the least modified by European land use. This is because they occur over sandplains, dunefields and rocky ranges, largely unsuitable for any pastoral development other than sparse grazing. Much of the hummock grass vegetation lies within vacant Crown lands, undeveloped Aboriginal lands or nature conservation reserves.

Snappy gum and spinifex
Snappy gum (E. brevifolia) *is a common species of the low open woodlands of the north-west. It is shown here over* Triodia *on stony hills near Halls Creek (WA). There are about 35 species of* Triodia *and about 11 of* Plectrachne. *They can be divided into 'hard' and 'soft' groups depending on leaf anatomy. Many are highly flammable; the desert sandplains are therefore a mosaic of different stages of spinifex and shrub regrowth since the last fire.*

Hummock grassland H2
10–30% foliage cover

Virtually pure hummock grasslands (**H2**), described by Beard (1967) as 'grass steppe', are largely restricted to rocky ranges and some dune areas. There are also areas within the great expanses of sandy country mapped as **wS1tH** where the shrub stratum is virtually absent. Likewise, trees are absent from some steep and rocky places within the limits of **eL1tH** and **xL1tH** in north-western and central Australia.

Triodia pungens is widespread in the mapped examples of **tH2**, but some species are regionally important, such as *T. clelandii* in central Australia and *T. wiseana* in the north-west. The plants are well spaced and the overall cover is therefore open; projective foliage cover is generally within the 10–30% range, but may be outside these limits due to soil or regeneration differences. In general, these hummock grasslands occur in inhospitable or inaccessible situations and are little used.

An area of low sand dunes on the eastern side of Lake Eyre is stabilised by a sparse cover of the grass *Zygochloa paradoxa* with some *Triodia* and occasional shrubs of *Acacia ligulata*. *Zygochloa* resembles *Triodia* in forming a mass of repeatedly branched stems up to a metre in height, but has shorter leaves which are not spine-like. This some-what anomalous grass is, however, regarded as a hummock grass and the vegetation is mapped as **xH2**.

Spinifex on rocky hill country in the Pilbara region (WA)
*Hummock grassland with few trees or shrubs has been described as 'grass steppe' because of its visual similarity to the steppes of central Asia. The largest examples of this formation (***tH2***) are in WA, but others occur on rocky ranges in the NT, Qld and SA. In terms of the vast areas where hummock grasses are the dominant understorey, grass steppe is a relatively limited vegetation type in Australia.*

Tussocky or tufted grasses and graminoids G

Almost endless plains of tussock grasses are as much a distinctive Australian vegetation type as are the eucalypt woodlands or desert hummock grasslands. In Qld and on the Barkly Tableland of the NT the treeless Mitchell grass downs cover many thousands of square kilometres.

This category of herbaceous plants also includes the grass-like sedges and extends over the full range of cover classes. It dominates vegetation as diverse as the Top End floodplain sedgelands and the very sparse grasses of the arid inland plains. The advent of European land uses has seen a large increase in the extent of grassland involving both native and exotic species.

Closed tussock grassland or sedgeland G4

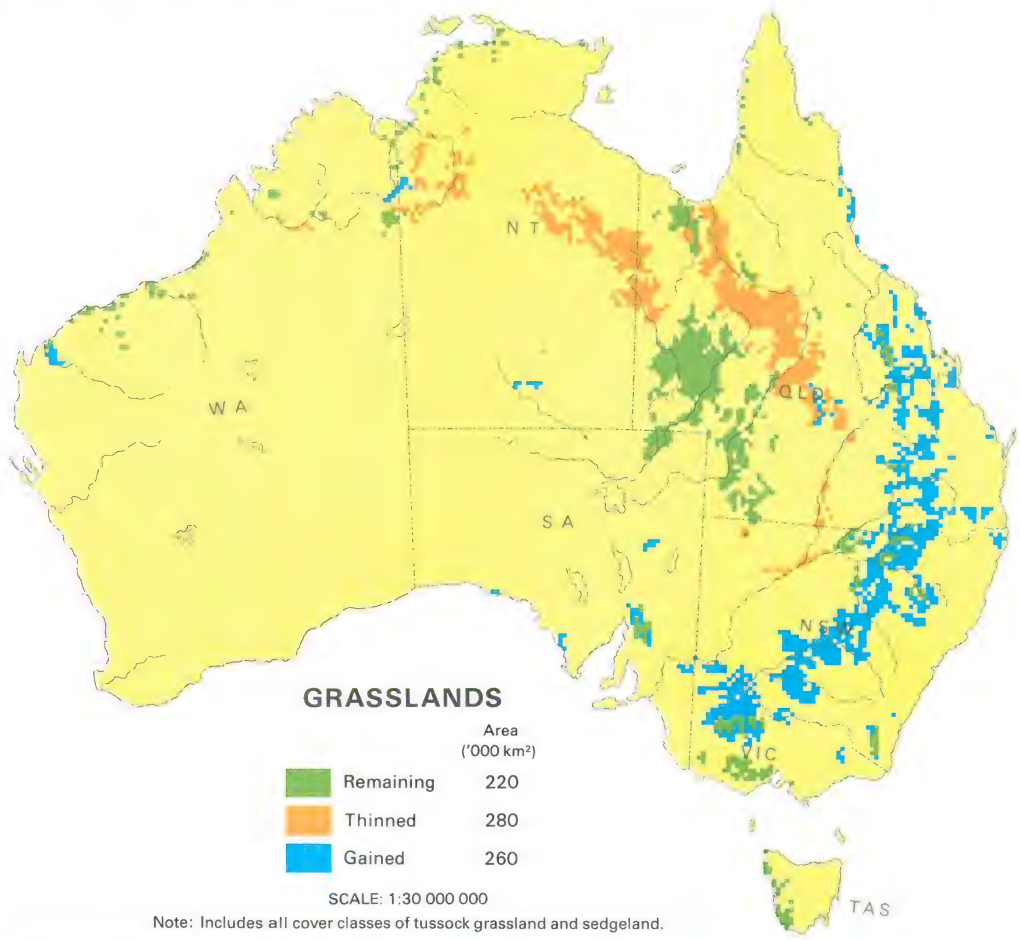
>70% foliage cover

The largest areas of this formation, which includes both natural and cultural vegetation types, are found on floodplains and lowlands in coastal regions across northern Australia. In the Top End of the NT the lower courses of many streams are bordered by wide estuarine plains that are flooded throughout the wet season. The heavy soils of these plains are covered by dense stands of tussocky or tufted grasses and sedges. The principal grasses include *Oryza rufipogon* and *O. australiensis*, with several species of *Eleocharis* and *Cyperus* prominent among the sedges.

Some examples are dominated by the sedges (Cyperaceae) and are mapped accordingly (**gG4**), but in the areas south-west of Darwin the grasses are co-dominant (**gyG4**). Feral water buffaloes may have reduced the grass component in some areas, and may also have contributed to the spread of such exotic volunteer species as the thorny shrub *Mimosa pigra* and the forb *Hyptis suaveolens* (Considine 1985a, 1985b).

Tropical coastal saline soils adjacent to some littoral areas support grasslands that vary in both composition and density, but appear in general to belong to this structural form. These have a wide range of tussocky or tufted grasses (**yG4**), including *Sporobolus virginicus* and species of *Xerochloa*, and some sedges. The areas mapped as **yG4** near Rockhampton are more extensive in the present vegetation because of the clearing of adjacent wooded areas. In these extended areas the saline grasses, such as *Sporobolus*, are mixed with other species, including the native *Themeda australis* and *Heteropogon contortus*, the sown exotics *Chloris gayana* and *Panicum maximum*, and some summer crops, especially grain sorghum (*Sorghum bicolor*).

On the Present Vegetation map, plantations of sugar cane (*Saccharum* cultivars) are shown as **vG4** because they are structurally classed as tall dense tussock grasslands. These plantations are now the principal vegetation on many lowlands along the east coast of Qld, though they are often associated with areas of sown or native pasture. They have been established on sites formerly occupied by closed forest, open forest or woodland.



Fields of sugar cane
*A new and distinctive vegetation type—sugar cane—has replaced the former forests and woodlands of many fertile coastal areas in Qld. The cultivated and irrigated fields of sugar cane are coded as dense tussock grassland (**vG4**), although taller than other grasslands. Sugar cane belongs to the grass genus* Saccharum. *A small amount is also grown in NSW, but about 95% of the 3000 km² annually planted to sugar cane is in Qld.*

Kakadu Wetlands
The seasonally inundated floodplains of many northern Australian rivers carry dense stands of grasses and sedges. The highest density of this wetland vegetation follows flooding and reaches a peak with 'the Wet'. Eleocharis dulcis, *a spike-rush (pictured), is a common graminoid plant of the wetter areas and lagoons, often bordered by* Pandanus *on higher ground.*

Tussocky or tufted grasses and graminoids G

Tussock grassland or sedgeland G3

30–70% foliage cover

Mitchell grass is the most extensive of the natural tussock grasslands (**aG3**), but the largest areas on the Present Vegetation map have a range of dominant genera (**yG3**). Despite a large increase in agricultural areas, there has been a decrease in the total area of this structural form since European settlement because of the present coding of much of the Mitchell grass as open tussock grassland (**aG2**).

The new agricultural grasslands, which form a broad arc from northern Qld to SA, largely result from clearance in woody natural vegetation types. They are made up of both native grasses and either sown or volunteer exotic species. As the principal land use in these grasslands is livestock grazing, often alternating with seasonal cropping, much of the landscape is a mosaic of pasture and crop paddocks.

Many genera are represented in the induced or modified native grasslands, including *Astrebla*, *Dichanthium* and *Heteropogon* in the north and *Stipa*, *Danthonia* and *Poa* in the south, with *Aristida*, *Bothriochloa* and *Panicum* being fairly widespread. On the formerly forested land on Flinders Island, in Bass Strait, sedges (**ygG3**) are also prominent. Since the 1950s, large areas in Qld (for example on the clay soils of the former brigalow lands) have been sown to exotic tussocky or tufted grasses such as *Panicum maximum*, *Chloris gayana* and *Cenchrus ciliaris*.

In the south the associated crops are mostly winter cereals, primarily wheat (*Triticum* cultivars), barley (*Hordeum* cultivars) and oats (*Avena* cultivars), shown on the map by open circles. Winter crops are important in Qld and northern NSW but summer crops (triangle symbols) are also grown, notably grain sorghum (*Sorghum bicolor*) and sunflower (*Helianthus annuus*), with some areas of cotton (*Gossypium hirsutum*).

In north-western Australia, many clay plains are mapped as **yG3** on the Present Vegetation map. The grasses include *Aristida*, *Astrebla*, *Chrysopogon*, *Dichanthium* and *Sorghum*, which in some places have been supplemented by sowing *Cenchrus ciliaris*. Some stands are naturally occurring but may have been extended by the removal of former shrub cover, as in the area south of Onslow. Others result from former stands of **aG3** or **dG3** becoming more mixed under grazing. Along the Fitzroy River grazing has reduced the overall cover to **yG2**. Some seasonal crops are grown in the mapped grassland area in the lower Ord valley.

On the basaltic plains west of Melbourne the former *Themeda*, *Danthonia*, *Poa* and *Stipa* grasslands are largely replaced by sown pastures (**yfF3**). The natural grassland of the shallow stony soils around Jamestown (SA) was made up of *Danthonia*, *Stipa* and species of the graminoid *Lomandra*. Some parts of this vegetation have been modified but others are still recognisable.

There are only a few areas of *Astrebla* grassland in the north and east which remain as **aG3** on the Present Vegetation map. Much larger areas of *Astrebla* grassland are now coded as open tussock grassland (**aG2**) because of the effects of grazing. *Astrebla* is replaced in higher rainfall areas by *Dichanthium* (**dG3**), together with *Eulalia fulva* and species of *Aristida* and *Bothriochloa*. There is much more overlap in the distributions of the genera than might be implied from the small mapped areas of **daG3**.

A large part of the *Dichanthium* grassland (**dG3**) is also now mapped as **dG2**. On the Darling Downs of south-eastern Qld an area of former *D. sericeum* grassland is now used for an alternation of summer and winter crops. Grassland is now only a minor component and is therefore not shown on the Present Vegetation map.

Some areas of natural grassland, such as the *Stipa* (**sG3**) areas in the south-east and parts of the *Dichanthium* (**dG3**) and *Astrebla* (**aG3**) grasslands further north, have retained the same structure, but are now more mixed (**yG3**).

Two examples of this form are sedgelands dominated by large tussocky members of the Cyperaceae (**gG3**). One is in the natural vegetation of south-eastern SA where species of *Gahnia*, other graminoids and grasses grew in seasonally flooded coastal lowlands. These have been drained and now carry sown pastures which are generalised within the wider open woodlands on the Present Vegetation map (**eM1yfF**, **eL1yfF**).

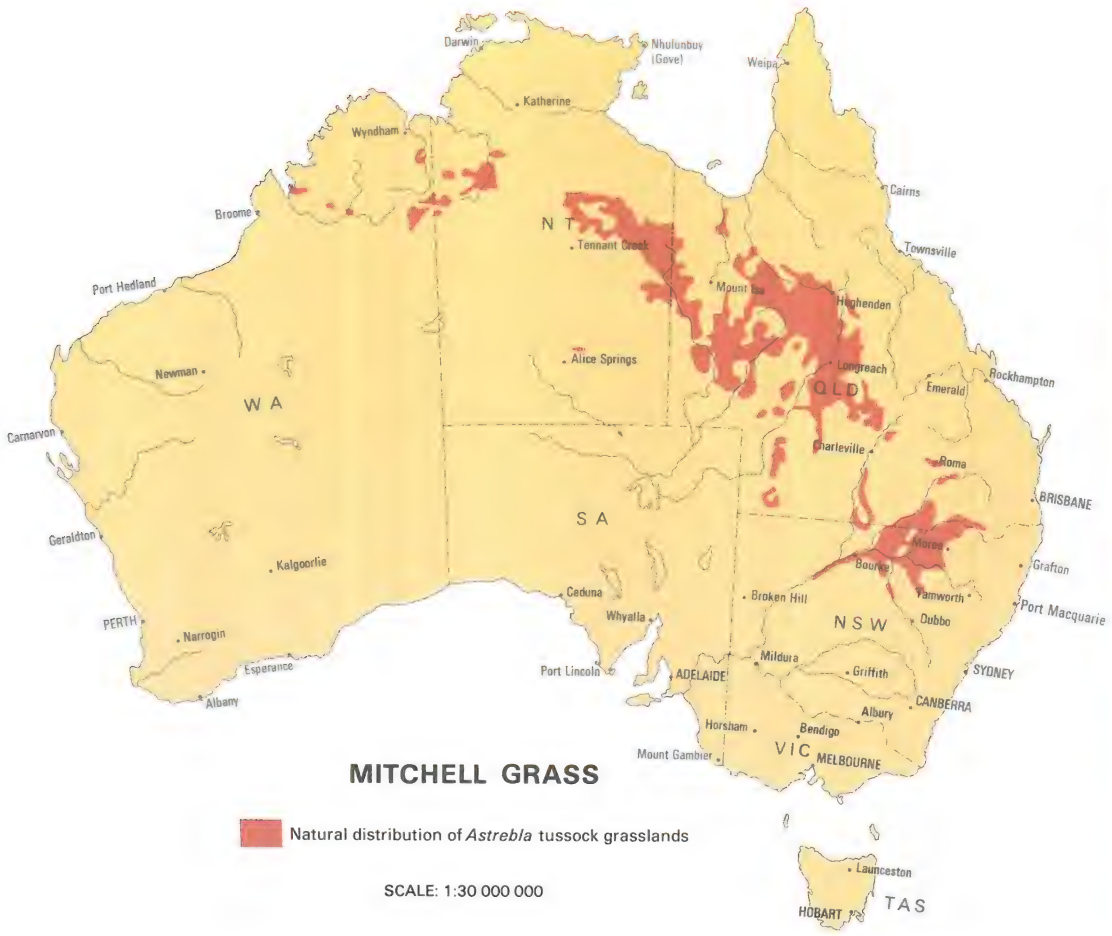
The other example is in western Tas. and extends from coastal plains to mountainous areas, associated with peat-covered bleached sands. The distinctive sedge *Gymnoschoenus sphaerocephalus* is a constant species (see photo opposite), but it occurs in a mosaic with other graminoids, especially Cyperaceae and Restionaceae, and small shrubs including Epacridaceae and Myrtaceae. Fire has been a significant factor in the environment of this type, both under Aboriginal occupation and since European settlement (Jackson 1981).

MITCHELL GRASS

The natural extent of the *Astrebla* tussock grasslands is shown on this map, including areas where the species occur as understorey components. Mitchell grass is primarily associated with self-mulching cracking clay soils across northern Australia. The four species of *Astrebla* are *A. lappacea*, *A. pectinata*, *A. squarrosa* and *A. elymoides*.

On the Natural Vegetation map the Mitchell grass downs stand out clearly as areas coded **aG3**, with areas of Queensland bluegrass (**dG3**) on their wetter margins. The Present Vegetation map shows most of these areas as **aG2**, reflecting the lower foliage cover under grazing. This is a result of grazed tussocks being kept compact under continuous grazing and of an actual reduction in tussock numbers. However, Mitchell grass has proved to be a highly resilient plant community, even after more than a century of grazing by both sheep and cattle.

The recent invasion of the exotic prickly acacia (*Acacia nilotica*) has had a major impact on the appearance of the Mitchell grass downs. It forms an open tree savanna coded as **wL1aG** over the north-eastern section of the former treeless plains.



Tussock grasses G

Open tussock grassland G2

10–30% foliage cover

Most of the Mitchell grass (*Astrebla*) country across eastern and northern Australia is coded as open tussock grassland (**aG2**) on the Present Vegetation map. The effects of grazing have led to an overall reduction in cover on the Mitchell grass downs, while in the drier inland areas of south-western Qld Mitchell grass is naturally less dense and more mixed in composition.

Astrebla grasslands are found mainly on cracking clay soils in summer rainfall areas within the 200–600 mm annual rainfall range. They are widespread on the downs of north-central Qld and on the Barkly Tableland extending into the NT. There are lesser areas further to the north-west, for example around Inverway in the NT. *Astrebla* species extend much further into the arid zone than the mapped areas of **aG2** and are a component of the vegetation of the gibber country in Qld and SA, where they occur in depressions.

The principal species are *Astrebla lappacea* and *A. pectinata*, the former being prominent in the east and the latter in the north and in the lower rainfall areas. Some stands contain few other grasses but in others there is a range of species of such genera as *Aristida* and *Eragrostis*.

Astrebla grasslands are favoured pasture for beef cattle in the north and west, and for sheep in the south-east of their range. They have been reduced in some areas but in general they have proved remarkably persistent under grazing. Foliage cover may fluctuate greatly under the combined influences of grazing and seasonal conditions, and their present coding as **aG2** is a broad generalisation.

Many natural *Dichanthium* grasslands (**dG3**), particularly in the NT and on the lower floodplains of the Flinders River system in Qld, have also suffered a decline in cover as a result of continued grazing and are now coded as **dG2**. Some present areas of **yG2** also result from the grazing of former tussock grasslands (**aG3**, **yG3**). Others result from the clearing of a range of natural vegetation types dominated by trees or shrubs and in some of these areas the native grasses have been supplemented by sowing drought-tolerant exotic grasses.

A notable example of **yG2** is on part of the catchment of the Ord River, where the former *Eucalyptus* grassy low open woodland (**eL1yG**) was largely eliminated under grazing, leaving the ground bare, unproductive, and eroded. To rehabilitate this area the small exotic shrub *Aerva javanica* has been planted as a coloniser, along with the exotic buffel (*Cenchrus ciliaris*) and birdwood (*C. setiger*) grasses.

Along the broad floodplains of the rivers in south-western Qld (the Channel Country), a fluctuating and largely herbaceous natural vegetation type is coded as **yG2**. These alluvial plains up to 60 km wide carry intermittent floodwaters through the western interior of Qld and, with the local annual rainfall below 250 mm, this has a major influence on vegetation growth.

The well defined Channel Country watercourses are marked by lines of low trees, notably *Eucalyptus microtheca*, *Acacia cambagei* and *A. stenophylla*, and the moister depressions carry stands of such species as the tall perennial grass *Eragrostis australasica* and the low shrub *Muehlenbeckia cunninghamii*.

The greater part of the Channel Country floodplains has a mixed herbaceous cover of grasses, such as *Chloris*, *Eragrostis* and *Panicum*, and forbs, including species of *Ptilotus* and members of the Chenopodiaceae and Asteraceae. Certain species, notably the grasses *Echinochloa turnerana* and *Panicum whitei* and the legume *Trigonella suavissima*, are particularly prominent after flooding and, while they last, provide valuable feed for beef cattle.

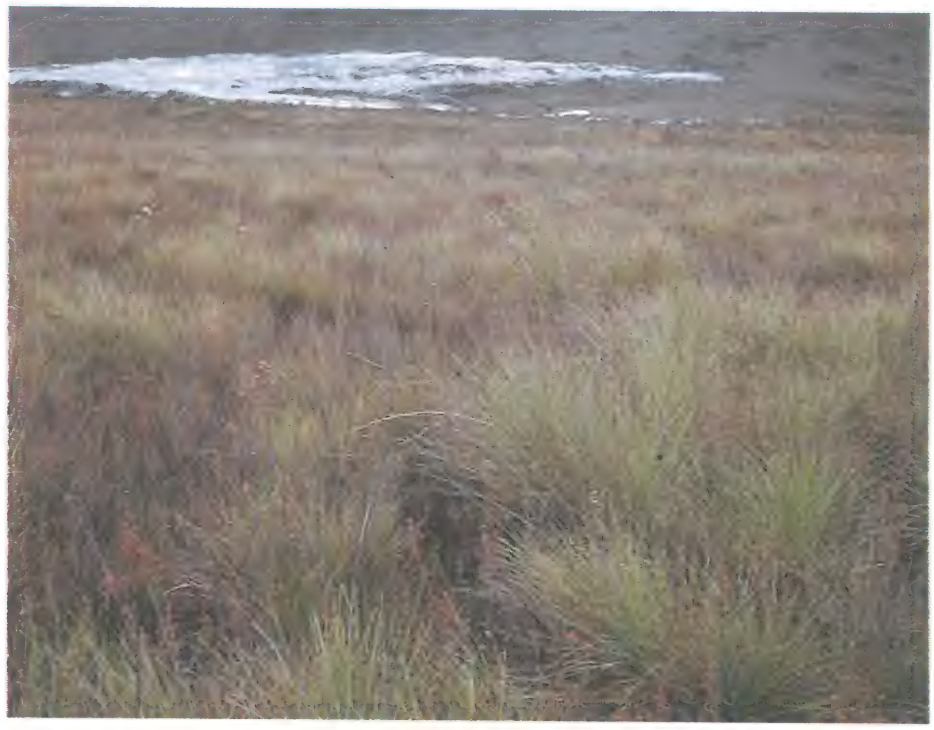
Sparse open tussock grassland G1

<10% foliage cover

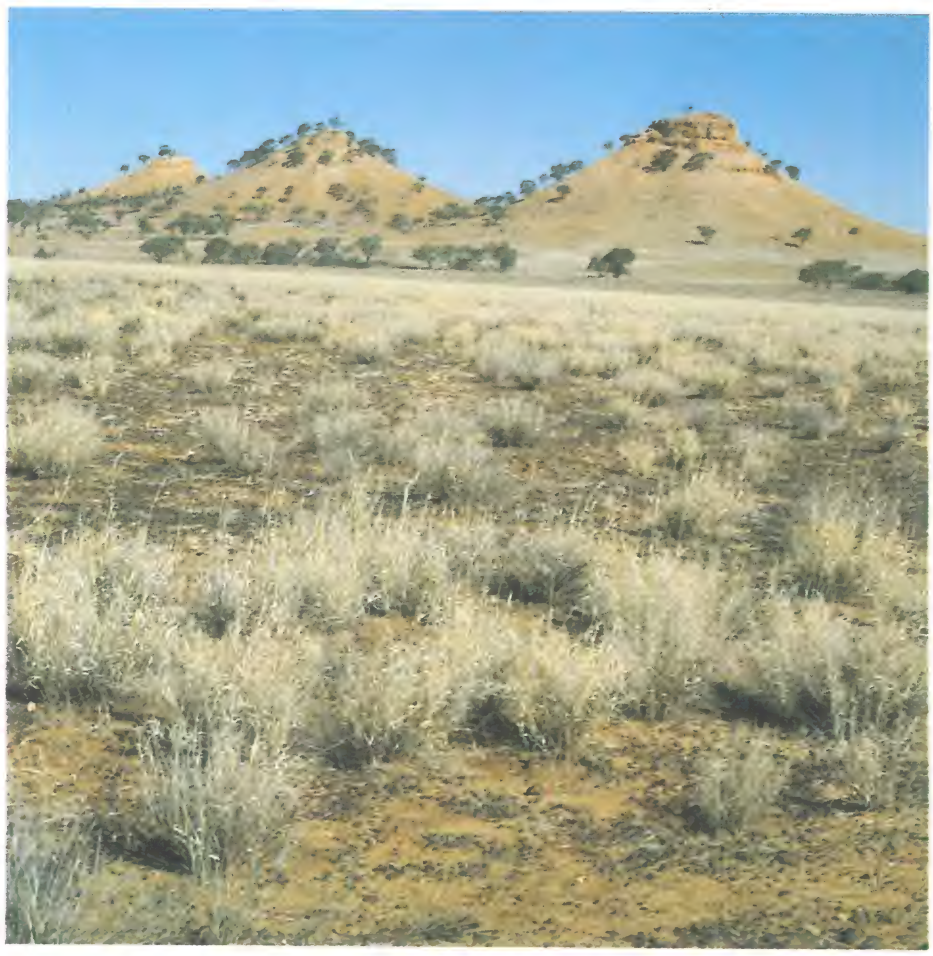
The name 'sparse open tussock grassland' is based on the terminology of Specht (1970) but was not used by him. Most of the mapped examples of this structural form (**yG1**) occur towards the western margins of the vegetation of the Channel Country (**yG2**) and may reflect the combined effects of lower rainfall and less flooding.

This vegetation type occurs mainly on clay plains, which are crossed by sand dunes in some areas (**yG1**). Foliage cover fluctuates with seasonal conditions, but is generally very sparse. The tussock grasses include species of *Aristida*, *Sporobolus* and *Eragrostis*, and also *Astrebla* in some places; the forb component includes species of *Atriplex* and *Sclerolaena* and members of the Asteraceae.

One small area shown as **yG1** on the Present Vegetation map, on the Bulloo River overflow to the east of Tibooburra (NSW), appears to reflect the effects of grazing on former open tussock grassland.



Buttongrass moor in western Tas. Gymnoschoenus sphaerocephalus *is a prominent tussocky sedge throughout the vegetation mapped as* (**gG3**) *in western Tas. It is also found in swampy situations on the mainland. Plants of this species are up to one metre in height, with the distinctive flowering spikes projecting even higher.*



Open tussock grassland of Mitchell grass Astrebla *occurs naturally as open tussock grassland* (**aG2**) *over wide areas on the plains of south-western Qld. This open Mitchell grass country (pictured) is found on red and brown cracking clay soils, mostly in areas receiving less than 300 mm annual rainfall.* Astrebla pectinata, *or barley Mitchell grass, is the dominant species in these drier areas.*

The Ord Regeneration Area *The original vegetation of the plainlands of the Ord River catchment was a grassy low open woodland dominated by* Eucalyptus terminalis. *Parts of this area became severely degraded as a result of overgrazing, with a loss of both tree and ground cover. A large area was progressively destocked and revegetated during the 1960s. Rehabilitation efforts have involved the sowing of exotic grasses such as buffel* (Cenchrus ciliaris) *and the small exotic shrub* Aerva javanica.

Other herbaceous plants

Pasture and herbfield F

Sown pastures are made up almost entirely of exotic grasses and legumes and now cover about 5% of the continent. They are a new structural form of vegetation in this country. The nearest natural equivalents to sown pastures are the denser herbfields, forms occurring over very limited areas or existing only fleetingly as part of a herbaceous vegetation flush after rain.

In these mixtures of grasses and forbs many of the introduced grasses are sward-forming by nature and the tussocky species are kept short by grazing. The structure is therefore generally that of a low herbaceous sward. Sown pastures are maintained by repeated fertiliser applications, and those in the **F3** (30–70% cover) category often alternate with seasonal crops and thus may be largely annual, either being planted or appearing voluntarily.

Dense sown pasture (**F4**) and sown pasture (**F3**) appear only on the Present Vegetation map. Open herbfield (**F2**) is not shown on either map, but does occur during seasonal changes in sparse open herbfield (**F1**).

Dense sown pasture F4
>70% foliage cover

As there is no entirely appropriate term for this vegetation type in the terminology of Specht (1970), 'dense sown pasture' is proposed because of the predominance of sown exotic sward-forming grasses and legumes. However, volunteer exotic grasses, legumes and other forbs also occur within this vegetation form and even some native grasses, such as *Bothriochloa macra*, that can adopt the sward-forming habit under grazing.

Although most of the sown exotic grasses are grazed to low spreading swards, some species (such as *Cenchrus ciliaris*) remain tussocky or tufted and therefore coded as grasslands (**yG3**, **yG4**).

Many of the mapped areas of dense sown pasture in eastern Australia (**yfF4**, **yF4**) are dominated by perennial plants. They extend from northern Qld to Tas., mostly on land that was formerly covered by forest or woodland. Relic trees are a feature of many of these landscapes. In other areas natural vegetation has been entirely removed. Dense sown pasture occurs largely in coastal or near-coastal locations where the dense cover is maintained by regular rainfall, but there are also examples further inland—in the irrigation areas of southern NSW and northern Vic.

The number of introduced pasture species is large and growing. In order of increasing temperature requirement, important grasses are *Lolium perenne*, *Paspalum dilatatum*, *Pennisetum clandestinum*, *Digitaria decumbens* and species of *Brachiaria*; the legumes include *Trifolium repens* (and some seasonal *T. subterraneum*), *Neonotonia wightii*, species of *Desmodium*, and *Centrosema pubescens*. *Medicago sativa* is prominent in some temperate regions and is the dominant species of the irrigated pastures (**fyF4**) in the lower Hunter Valley.

The dense pastures are generally grazed by dairy or beef cattle, with some sheep in the south. In some of the mapped areas seasonal cropping is alternated with livestock grazing, although this occurs primarily with the following type (**F3**). The principal winter crops are wheat (*Triticum* cultivars), barley (*Hordeum* cultivars) and oats (*Avena* cultivars). The summer crops include grain sorghum (*Sorghum bicolor*) and peanut (*Arachis hypogaea*) in the north, and rice (*Oryza sativa*) in the irrigation areas of NSW.

In the south-west of WA, under a highly seasonal rainfall pattern of wet winters and dry summers, the dense sown pastures are dominated by seasonal species (***yfF4***). The characteristic species are *Lolium rigidum* and *Trifolium subterraneum*, though there is also a range of seasonal exotic volunteer grasses including species of *Bromus*, *Hordeum* and *Vulpia*, and legumes such as *Trifolium*.

The native bracken fern (*Pteridium esculentum*) occurs as a weed in many areas of dense seasonal and perennial sown pasture.

PASTURES

The map shows the major areas where introduced grass and legume pastures have been established to support livestock industries. Most of these exotic species are sown but, once established, many are self-generating. The pastures may be either seasonal or perennial.

Across southern Australia, most of the introduced pastures are grazed to a low sward and are structurally classed as **F3** or **F4**. The photo at right shows seasonal pasture (***yfF3***) and crops near Cowra (NSW) and that below is a dense sown pasture (**yfF4**) in west Gippsland (Vic.). Many introduced pastures in the north, however, are made up of tussocky or tufted grasses, which do not form a sward under grazing and are coded as **G3** or **G4**.

The maintenance of many of the introduced pastures is dependent upon artificial fertiliser and, on current rates of application, over 1 million tons of superphosphate are used on about 100 000 km^2 of pasture in Australia annually.

F

Sown pasture
30–70% foliage cover **F3**

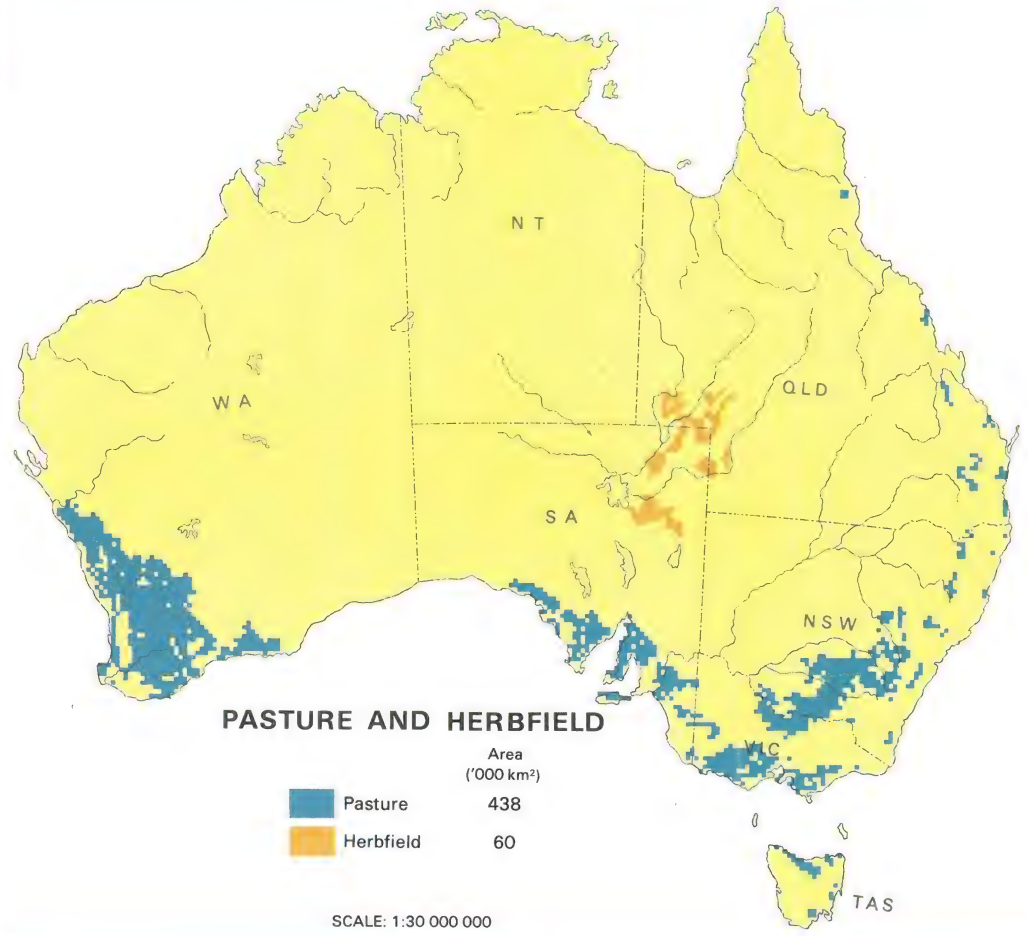
Sown pasture is similar to dense sown pasture, but in general is found in areas of lower rainfall or less fertile soils. Most of the sown pasture areas in the south-east and south-west of the continent lie within the major cereal cropping regions and are frequently of seasonal occurrence. Relic trees and shrubs are a feature of sown pasture landscapes but there are many areas where the natural vegetation has been entirely removed.

Sown pastures dominated by perennial sward-forming plants (**yfF3**, **yF3**) occur principally in south-eastern Australia on lands formerly occupied by forest, woodland and to a lesser extent by shrubland or tussock grassland. The characteristic species include the grasses *Lolium perenne* and *Phalaris aquatica*, and the legumes *Trifolium repens* and the seasonal *T. subterraneum*. A range of other exotic species, both sown and volunteer, is found in these pastures and also some native grasses, such as *Botriochloa macra*.

Much larger areas of sown pasture, generally under lower or more strongly seasonal rainfall patterns, are dominated by seasonal plants (***yfF3***, ***yF3***). Where these pastures occur in south-eastern and south-western Australia, they are on land formerly occupied by woodland, tall shrubland and open scrub. Over much of their mapped area, there is a marked winter rainfall maximum which favours cool season plants.

Livestock grazing, alternating in many areas with seasonal cropping, is the principal land use and the landscape often appears as a mosaic of crop and pasture paddocks. The principal winter cereal crop is wheat (*Triticum* cultivars), though barley (*Hordeum* cultivars) and oats (*Avena* cultivars) are also widespread. Lupins (*Lupinus* cultivars) are prominent in some places, notably north of Perth.

The principal sown legumes of the seasonal pastures are *Trifolium subterraneum* in better-watered areas, and species of *Medicago* under lower rainfalls. The grass *Lolium rigidum* is sown in some areas. There is also a range of volunteer exotics which may form a large proportion of the pasture. These include species of grasses from genera such as *Hordeum*, *Avena*, *Bromus* and *Vulpia* and the legume genera *Trifolium* and *Medicago* as well as other forbs such as the widespread weeds *Arctotheca calendula* and *Echium plantagineum* and members of the family Brassicaceae. Areas mapped as occupied by this vegetation type may include lesser areas of native tussock grassland.



Sparse open herbfield
<10% foliage cover **F1**

The name 'sparse open herbfield' is based on the terminology of Specht (1970) but was not used by him. Most of the mapped examples of this structural form are dominated by herbaceous members of the Chenopodiaceae (**kF1**). In general they occur naturally, although two examples shown in the western Simpson Desert on the Present Vegetation map appear to result from grazing on former low open shrubland (**kZ1yG**).

Sparse open herbfield occurs mainly in areas with less than 200 mm annual rainfall along the eastern margin of the Simpson Desert in Qld and south to Lake Frome (SA), where it is characteristic of duplex soils with dense mantles of stones ('gibbers'). Some gibber plains are overlain by widely spaced sand dunes.

The most common forbs are species of *Atriplex* and *Sclerolaena*, including *A. spongiosa*, *S. divaricata*, *S. eriacantha* and *S. lanicuspis*. Other species may be present, notably members of the Asteraceae. Vegetative cover and composition fluctuate greatly with seasonal conditions. In dry years virtually all vegetation disappears, while after rain it may thicken to open herbfield density, either with the chenopods still dominant (**kF2**) or with a wide range of genera (**xF2**).

Tussock grasses such as *Astrebla* may also become prominent in wet years, more particularly in areas not covered by gibbers. However, chenopod forbs are the most persistent elements and the vegetation of the desolate gibber country is therefore generalised as sparse open herbfield (**kF1**). An area of sparse open herbfield south-east of Lake Eyre is bordered by clay flats associated with a chain of saline ephemeral lakes. The vegetation of these flats is similar to that of the gibber country but is characterised by a range of floristic elements (**xF1**).

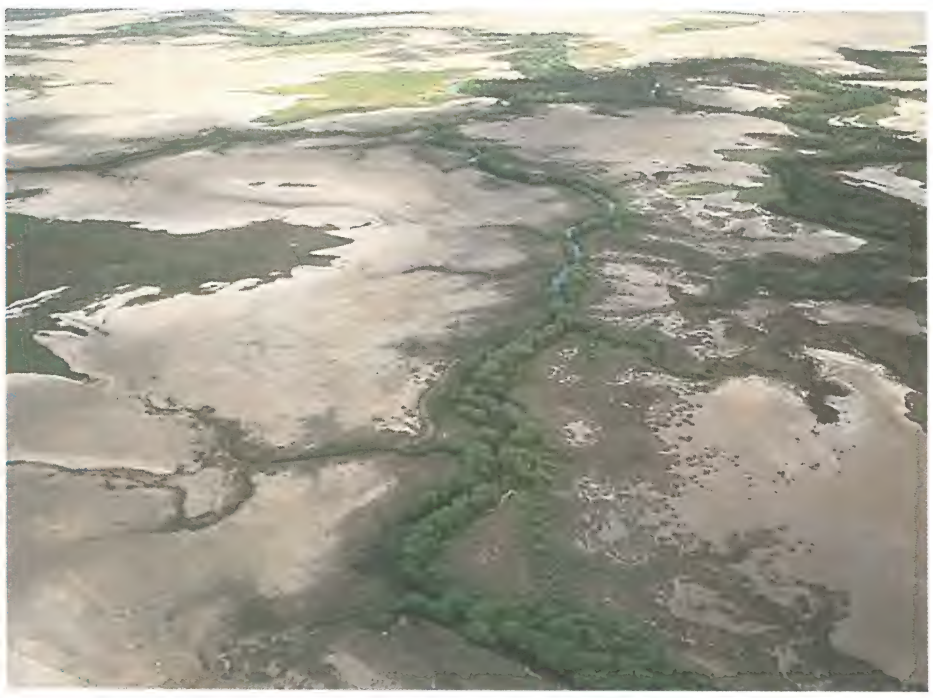
Settlement of these areas took place largely during the 1880s and a succession of good seasons created an over-optimistic view of the carrying capacity of this country. In subsequent years many holdings were abandoned along its drier margins. While much of this area is still part of functioning cattle properties, it is only lightly grazed and the adjacent Channel Country is the main source of stock feed.

Herbfield vegetation on gibber plains
This vegetation type is often little more than a scatter of dried out forbs and grasses for months, and sometimes years, at a time. But after big rains the same landscape may carry a denser cover of forbs and grasses (above). Both the amount of ground cover and the floristic composition fluctuate widely with seasonal conditions, but the gibber plains are more commonly in the desiccated state, shown in the photo at left, with persistent forbs of the genus Sclerolaena *(**kF1**) as the only ground cover.*

Other vegetation

Littoral complex

Low forest of grey mangrove in south-eastern Qld
Mangrove vegetation is best developed in the zone between mid-tide and high-tide and its characteristic form is that of low open forest, although its structure varies with the environmental gradient at right angles to the shoreline. The greatest diversity of species is found in the high rainfall area between Ingham and Innisfail in northern Qld. The grey mangrove (Avicennia marina) *is the most widespread species, occurring in the seaward part of nearly all mangrove communities. It is the only species of mangrove in Vic. and SA, where it barely reaches 3 m in height and often occurs as a shrub.*



Mangroves and mudflats, northern Australia
The ill-fated explorer Edmund Kennedy lost his life in the mangroves of Cape York Peninsula. Beale (1970) in his book about Kennedy, described such areas as: '...a monster spreadeagled in its own ooze and slime, to be touched at one's peril'. The image of mangrove swamps as useless and dangerous wastelands is rooted in Australia's colonial history, but is maintained even today to justify their draining and filling for development.

Red mangroves on the Top End shoreline
The plants which are found in the littoral zone are distinct from those of terrestrial habitats, although some strand line species occur on higher ground such as beach ridges. Littoral plants are adapted to high salt levels, waterlogging and the scouring effect of the tides; they exhibit such unusual morphological adaptations as are seen in mangrove roots and seeds. The red mangrove (Rhizophora styloza) *has distinctive stilt roots which enable it to anchor in semi-fluid and accreting substrates and to overcome the anaerobic soil conditions.*

A mosaic of different vegetation types occupies the extreme habitat of tidally inundated land around Australia's coastline. It is best developed on the wide tidal flats in the north, where there is low wave energy, a large tidal range and large estuarine sediment inputs.

At its most diverse, the littoral complex consists of a mosaic of mangrove stands, low shrublands, herbaceous communities and bare salt flats. It occupies saline soils within the limits of tidal flooding and is most prominent on the northern tropical shores, where extreme tidal ranges may be as great as 10 m. There are smaller, unmapped examples at many points along the extra-tropical coastline. Because of the variety of structural vegetation forms represented and its small total area, littoral vegetation is mapped as a complex.

The mangrove communities range in structure from closed forests to low open shrublands and in composition from assemblages of up to 30 species in northern tropical areas to pure stands of *Avicennia marina* on the southern coasts of the mainland. There are no mangroves in Tas. or on the southern coast of WA. A wide range of families is represented in the mangrove flora, notably the Rhizophoraceae. There are some deciduous trees (*Xylocarpus*) and even one species of palm, *Nypa fruticans*.

Mangrove stands usually occur on sites that are subject to regular tidal flooding. The other components are characteristic of sites that are less regularly flooded; under lower rainfall or markedly seasonal rainfall, the soils of such sites tend to be kept highly saline by evaporation (Macnae 1966).

The low shrublands are more diverse in southern Australia and are dominated by succulent species of Chenopodiaceae (**kZ2**); the principal genera represented are *Halosarcia*, *Sarcocornia* and *Sclerostegia*. In some areas these low shrublands tend structurally towards herbfields. The herbaceous communities are dominated by tussocky or tufted grasses and graminoids, often providing dense cover (**yG4**); *Sporobolus virginicus* is prominent among the grasses. Areas of extreme salinity are devoid of vegetation.

A striking feature of littoral communities is the zonation of species and vegetation types, which follows the gradient in environmental conditions at right angles to the shoreline. Mangroves are the most biologically productive component of the littoral vegetation and are recognised as important nursery habitats for the coastal fishing and oyster industries.

The total area of mangrove vegetation is about 11 500 km^2 (Galloway 1982). While the largest areas of mangroves occur on the northern shoreline and are little affected by human activities, in the south many swamps have been cleared, drained and filled for urban and coastal development.

Horticultural complex

The horticultural complex includes orchards and other fruit plantations, vineyards, and vegetable gardens. Examples are widespread in the more closely settled parts of the country, but only a few are large enough in area to be shown on the Present Vegetation map.

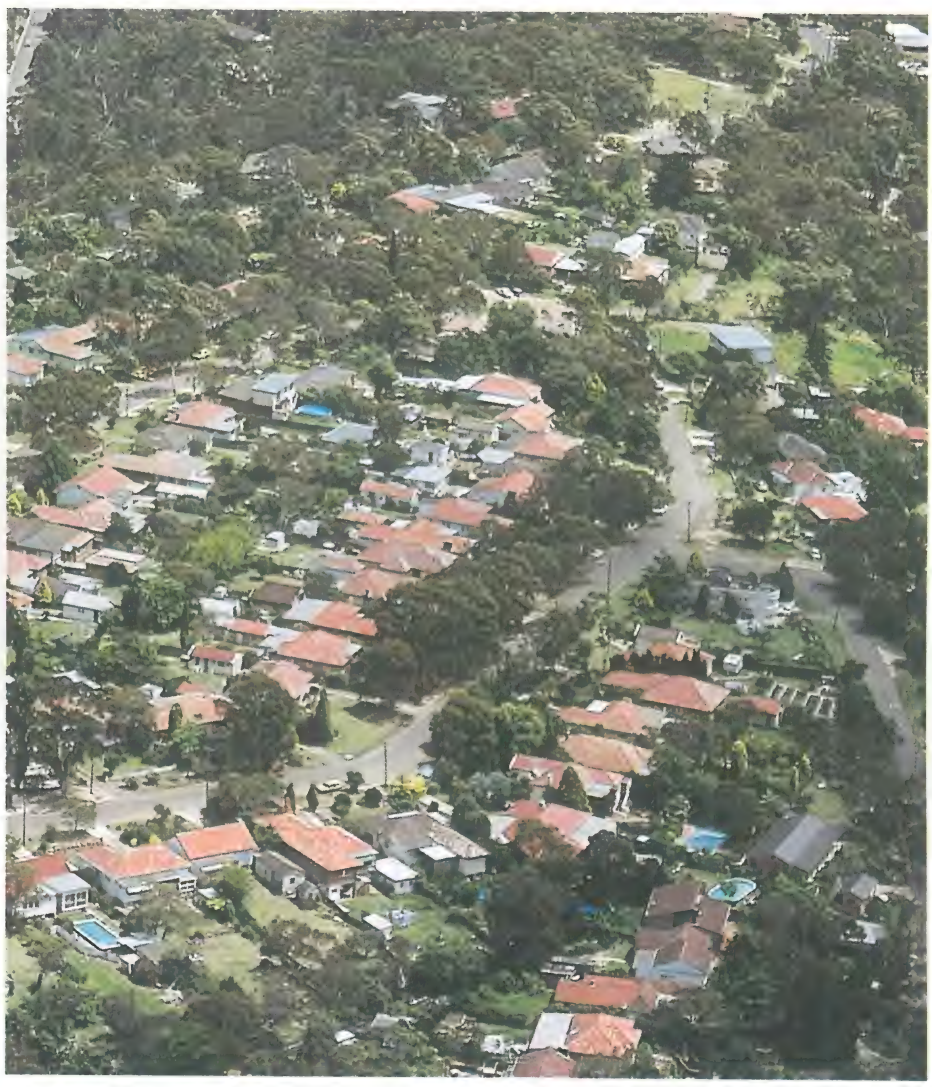
They are found in the vicinity of major cities, in irrigation areas and in other locations where climate and soil are suitable for this kind of land use. There are many small areas on alluvial flats along rivers in the south-east. In places the horticulture components are intricately mixed with sown pastures and seasonal crops.

Orchards of pome fruits (*Malus domestica* and *Pyrus communis*) and of stone fruits (species of *Prunus*) tend to occur towards the cooler climates and those of citrus fruits (species of *Citrus*) towards the warmer climates, but there is considerable overlap. Fruit plantations other than orchards occupy smaller and more localised areas. The principal fruits produced are pineapples (*Ananas comosus*) in Qld and bananas (*Musa* cultivars) in north-eastern NSW and in Qld.

The largest concentrations of grapevines (*Vitis vinifera*) are in the irrigation areas associated with the Murray and Murrumbidgee rivers and in the vicinity of Adelaide. There are many smaller areas of vineyards in suitable locations throughout temperate Australia.

The principal vegetables grown are potatoes (*Solanum tuberosum*) and peas (*Pisum sativum*) although Australia's broad climatic range allows a great variety of vegetables to be produced. In the past, plantations of coconut palms (*Cocos nucifera*) were maintained in the Cocos Islands.

Urban complex



Northern suburbs of Sydney
With the retention of many of the original trees and extensive street plantings, the overall vegetation cover of some suburban areas is open woodland or woodland. The mowed lawns of gardens and parklands are similar in structure to dense sown pasture.

Intensive horticulture near Griffith (NSW)
This scene from the Murrumbidgee Irrigation Area (far left) shows intensive horticultural use of land, primarily for citrus orchards. The sown pasture paddocks in the foreground are a feature of the vegetation of this mapped horticultural area.

Urban vegetation in Australia often stands in stark contrast to the surrounding bush or farmlands. This is particularly so in drier areas because the use of large amounts of water, fertiliser and human intervention in towns and suburbs produces a green and well-regulated landscape.

The vegetation of urban areas is a diverse assemblage of both exotic and native species. The major components include the trees of streets and parklands, the grasses of lawns and the many ornamental and useful garden plants. The re-creation of European style parklands with exotic trees over turf lawns, which require large inputs of water, remains the norm in urban areas. However, there is a growing trend towards 'bush' gardens, which simulate natural vegetation with a range of native species.

Within large cities there are identifiable spatial patterns of vegetative cover. Inner-city and industrial areas are often devoid of vegetation. In contrast, in well-established and affluent suburbs, where there is more open space, extensive tree plantings or selective initial clearing often approximate the overall tree density of woodlands. While there may be sharp boundaries between urban areas and natural vegetation or farmland, in other areas they may merge with market gardens, intensive horticulture or hobby farms.

The mining town of Newman (WA)
The transplantation of the suburban environment to remote areas in inland Australia often creates strong visual contrasts. Abrupt boundaries often occur between the green watered gardens and the dry and sparse natural vegetation.

Banana plantation, northern NSW
The northernmost mapped areas of horticulture are near Yeppoon and Brisbane in Qld. Most of Australia's banana crop, however, is grown on fertile, well drained soils in northern NSW (far left).

200 years of change

Major vegetation change

No species in Australia has had a more far-reaching effect upon the environment than humans. For thousands of years Aborigines changed vegetation patterns, mainly through the use of fire, but the advent of European settlement brought rapid and fundamental changes to the land cover. The changes to the flora are permanent and agricultural land use continues to encroach on areas of largely natural vegetation. The introduction of exotic flora and fauna also placed new pressures upon native ecosystems, the impacts of which are continuing and some of which are only now being realised.

This section deals with the major vegetation changes that are the result of European land use practices and treats some of the more significant examples in detail. The changes in the area occupied by different kinds of vegetation from before European settlement to the present are summarised in tables. They are discussed below under broad structural groupings of natural vegetation types.

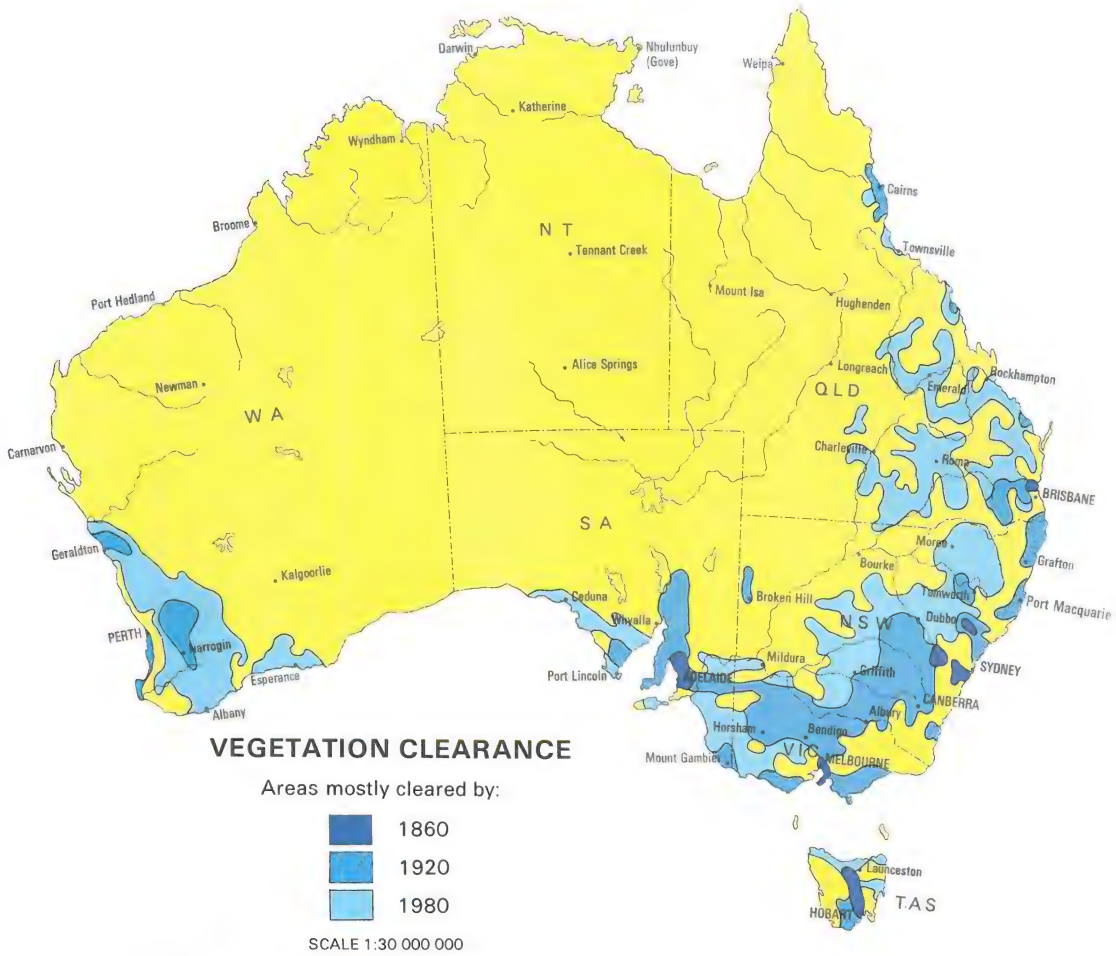
The problem of identifying the extent of the changes which have taken place is linked to the lack of information on the original flora. Many areas were affected by pastoralism before botanical surveys were undertaken and even today our knowledge of the existing flora of many regions is incomplete.

The direct impacts upon the landscape, such as the transformation of forests into pastures, are obvious and are shown on the 'Major Vegetation Changes' map. More subtle shifts in floristic composition or structure within the thresholds of the classification system may not have been detected. Other potentially more significant effects of these changes on the environment are only now becoming apparent. The unforseen consequences of large-scale vegetation clearance include widespread land salinisation and dieback, which are explained in more detail in the following pages.

The area now used for agriculture and forestry covers more than 5 million km^2 or nearly 70% of the continent, a scale of change barely imaginable to the first settlers. Although the maps suggest that the vegetation over much of this area has not been significantly altered, almost all of the grazing lands have been modified by the new selective forces imposed by exotic herbivores.

These changes have had least impact in rugged and remote areas; those lands that are largely unusable. The pastoral expansion of the last century saw virtually all suitable grazing land taken up. What remained has largely determined the distribution of today's conservation areas. For example, the vegetation of the sandstone tablelands surrounding the country's first and largest city, Sydney, was bypassed as non-productive and was left largely intact. The forested ranges of eastern Australia remain mostly uncleared, but to a large extent are devoted to another land use—timber production.

The sphere of European influence on the vegetation extends beyond the direct impacts of new land uses. The effects of the spread of feral animals and plants go far beyond the limits of agricultural location. The encroachment of grazing into Australia'a desert areas, for example, has gone little further than the boundaries established before 1900, and has even contracted in places. The unoccupied areas offer little feed to the grazier but increasing numbers of feral animals, notably rabbits, horses, donkeys, camels and goats, are modifying the vegetation of these regions.



SOURCES: Adapted from maps in *Australians: A Historical Atlas* (1987) and 1:5 million map 'Present Vegetation.'

Table 1: Mapped area of vegetation structural forms

Code	*Structural form*	*Natural area* '000 km^2	*Natural area* %	*Present area* '000 km^2	*Present area* %
T4	Tall closed forest	1	—	—	—
T3	Tall open forest	62	0.8	51	.7
M4	Closed forest	37	0.5	34	0.4
M3	Open forest	547	7.1	274	3.5
M2	Woodland	1003	13.1	614	8.0
M1	Open woodland	174	2.3	402	5.2
L4	Low closed forest	8	—	2	—
L3	Low open forest	33	0.4	34	0.4
L2	Low woodland	571	7.4	452	5.9
L1	Low open woodland	1476	19.2	1583	20.6
S3	Open scrub	90	1.2	28	0.4
S2	Tall shrubland	1138	14.8	741	9.6
S1	Tall open shrubland	1363	17.7	1623	21.1
Z3	Open heath	13	0.2	26	0.3
Z2	Low shrubland	372	4.8	57	0.7
Z1	Low open shrubland	101	1.3	401	5.2
H2	Hummock grassland	45	0.6	45	0.6
G4	Closed grassland/sedgeland	14	0.2	25	0.3
G3	Tussock grassland/sedgeland	359	4.7	326	4.2
G2	Open tussock grassland	115	1.5	348	4.5
G1	Sparse grassland	14	0.2	15	0.2
F4	Dense sown pasture	—	—	73	0.9
F3	Sown pasture	—	—	363	4.7
F1	Sparse open herbfield	59	0.8	59	0.8
	Littoral complex	22	0.3	22	0.3
	Urban complex	—	—	7	0.1
	Horticulture/intensive cropping	—	—	11	0.1
	No vegetation	65	0.8	66	0.8
	Total	**7682**	**100**	**7682**	**100**

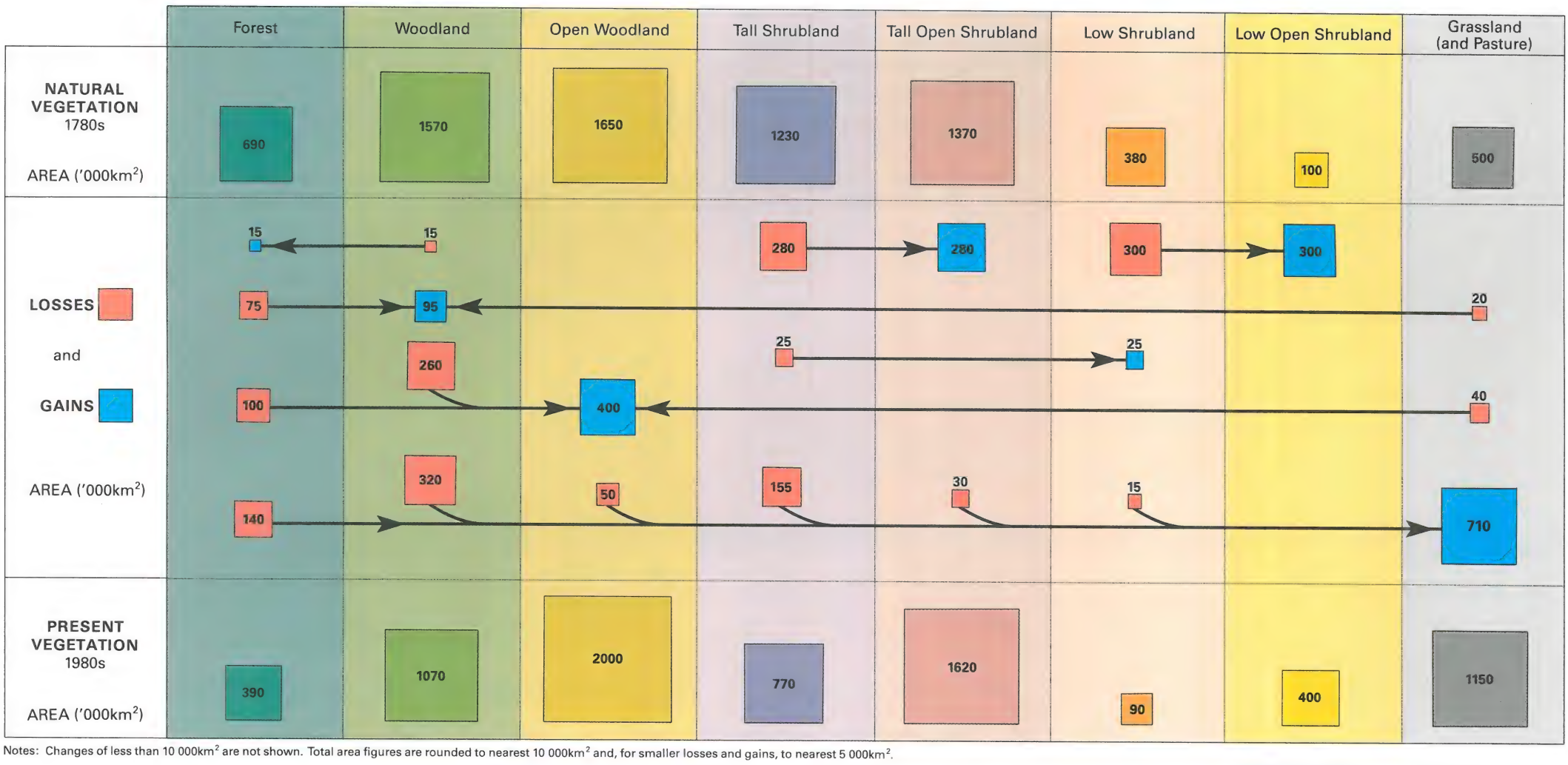
Table 2: Mapped area of understorey growth forms

Code	*Growth form*	*Natural area* '000 km^2	*Natural area* %	*Present area* '000 km^2	*Present area* %
M	Medium trees	11	0.2	9	0.15
L	Low trees	647	8.5	341	4.4
S	Tall shrubs	248	3.3	208	2.7
Z	Low shrubs	1433	19.0	946	12.3
H	Hummock grasses	2045	26.9	2065	26.8
G	Tussock grasses	2385	31.0	2308	30.0
F	Other herbaceous plants	64	0.8	141	1.8

The tables give estimates, based on the Natural Vegetation and Present Vegetation maps, of the area occupied by each structural form of vegetation and by the different understorey types. The maps were digitally scanned and the data resampled to a 4 x 4 km grid. For the widespread vegetation forms the estimates are accurate to within a few percent of the actual mapped areas, but for forms which cover a small area they are only approximate. The area figures are rounded to the nearest 1000 km^2 and are expressed as a percentage of the total area of Australia.

Cleared woodland
Prior to the 1860s, most clearing was confined to the vicinity of settlements. With the move to wheat production and the extra available labour after the gold rush, large-scale ring-barking and clearing with axe and fire began. The advent of heavy machinery for clearing and pulling greatly accelerated agricultural expansion in the 20th century.

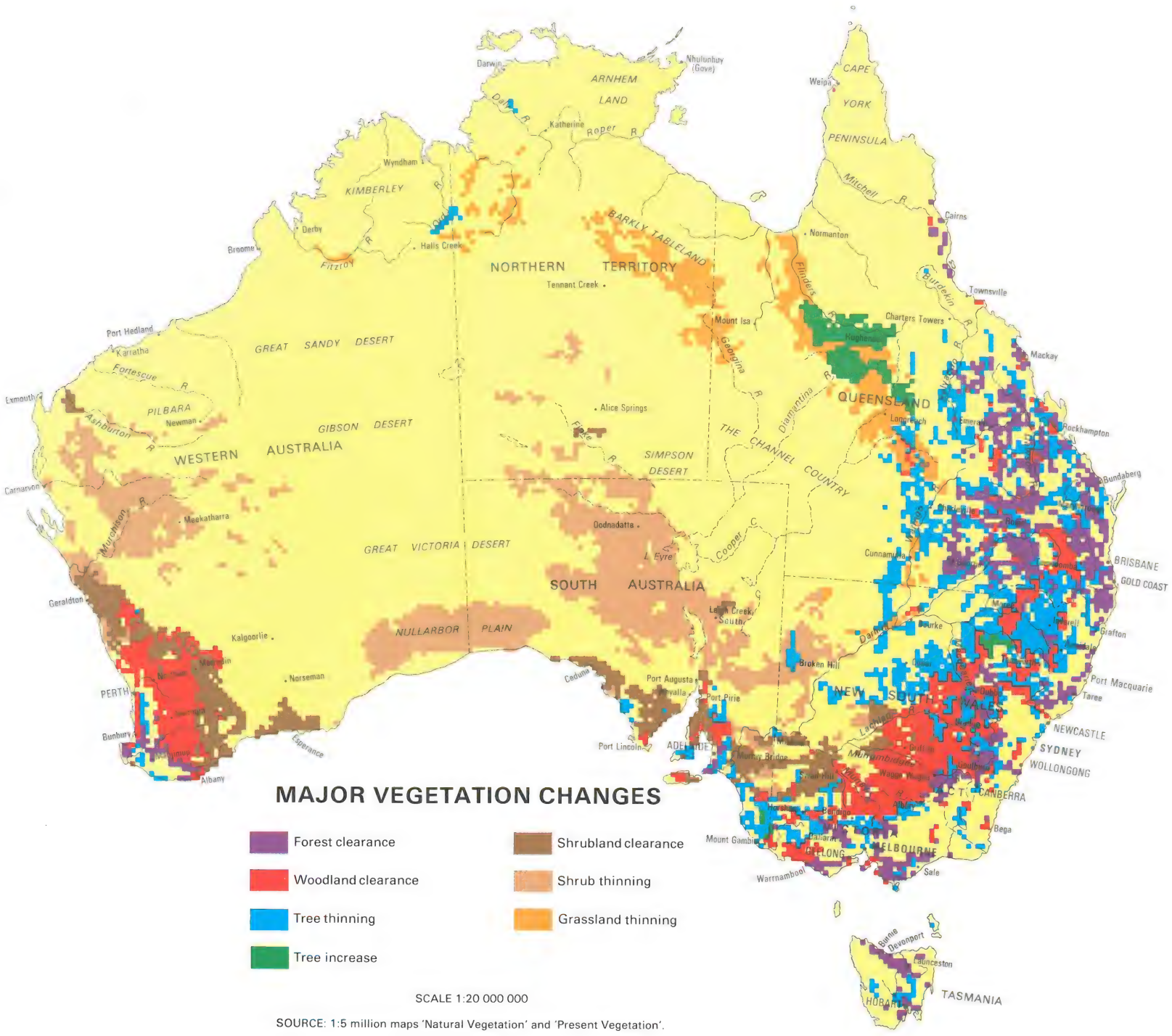
CHANGE IN AREA OF VEGETATION TYPES, 1780s–1980s



Notes: Changes of less than 10 000km² are not shown. Total area figures are rounded to nearest 10 000km² and, for smaller losses and gains, to nearest 5 000km².

This diagram summarises the area of the major changes to vegetation structure in the last 200 years. The structural forms are aggregated into broader groupings: forest for example covers both open and closed forests and all tree heights. Hummock grassland and open herbfield are not included as their areas are unchanged.

The total change in each broad vegetation type is broken down into the respective losses and gains in area from other types, shown by the horizontal lines. Open woodland, for example, has increased from 1650 000 km² to 2000 000 km². The gain of 410 000 km² comes from former forest (100 000), woodland (270 000) and grassland (40 000), offset by a loss of 50 000 km² to grassland and pasture.



MAJOR VEGETATION CHANGES

- Forest clearance
- Woodland clearance
- Tree thinning
- Tree increase
- Shrubland clearance
- Shrub thinning
- Grassland thinning

SCALE 1:20 000 000

SOURCE: 1:5 million maps 'Natural Vegetation' and 'Present Vegetation'.

The major historical changes in vegetation structure are identified on this map. The most dramatic change in terms of biomass loss has been that from forest to grassland or pasture. The clearing of eucalypt woodland, and of shrubland in drier areas, has given rise to the wheatbelt in the the south-east and south-west. Most of the cleared shrubland was mallee, with some areas of scrub and mallee-heath in WA.

Areas where the natural vegetation has been thinned but not entirely cleared are shown in separate categories. The change from forest to woodland or woodland to open woodland by partial clearing, thinning or regrowth is shown as tree thinning. The reduced shrub cover in the mulga tall shrublands and the chenopod low shrublands accounts for most of the area of shrub thinning.

The most extensive natural grassland, the Mitchell grass, is subject to large seasonal fluctuations, but continuous grazing has brought about an overall reduction in foliage cover over much of its range. This is shown as grassland thinning. The most significant example of tree increase is the area now occupied by the exotic *Acacia nilotica* in north-central Qld.

Forest change

Some of the most dramatic examples of human impact on the natural vegetation are seen at the abrupt boundaries between the forests and the farmlands. Here, towering complex formations give way to grazed swards of exotic pasture species. This has been the fate of large areas of former forest, but in other areas partial clearing and thinning have created woodlands and open woodlands.

In general, forests grow in areas climatically suited to agriculture and it is those on arable lands which have been cleared. The loss of the lowland rainforests (**xT4**) in northern Qld for sugar cane and the almost total clearance of the brigalow open forests (**wM3L**) for sown pasture and seasonal cropping are prime examples. The map below shows the former distribution of brigalow forests. Numerous areas of rainforest along the east coast, and large areas of eucalypt open forest have also been cleared for agriculture. Many of the forests that remain are on rugged terrain and about half are currently managed for timber production.

In terms of the structural classification the total area of all forest types has declined by about 40%, from 688 000 km^2 to 395 000 km^2. The actual difference in area is somewhat greater because the total forested area includes some forest plantation areas. The greater part of this reduction has been the loss of about half of the open forests (**M3**) through clearing or thinning.

The total area of plantation forests, which are shown on the map opposite, has more than doubled over the last twenty years. Plantations are providing an increasing proportion of Australia's timber and pulp needs and their expansion is seen as an important potential supplement to timber extracted from from native forests.

The variety of present uses of former forest lands includes: perennial cropping, such as sugar (**vG4**) along the Qld coast; exotic tussock grasslands (**yG3**) and summer seasonal crops, chiefly sorghum and sunflower, in central Qld; and improved pastures (**yfF4**, **eM1yF**) in the east and south-west of the country.

The structure and floristic composition of some forests have been affected by timber extraction and forest management practices. Fires, both wildfire and controlled burning of the lower strata, have tended to establish and maintain grassy understoreys. Grazing, mining and recreation have also made localised impacts within the forests.

Not all forest decline has been the direct result of human activities. The dieback within the jarrah forests of WA, for example, is linked to the spread of a fungus disease inadvertently transported by movements of machinery and people.

Brigalow country

In its natural state brigalow (*Acacia harpophylla*) covered about 6 million ha of central Qld and northern NSW, occurring either in dense uniform forests or in association with a number of other trees such as belah (*Casuarina cristata*), gidgee (*Acacia cambagei*), eucalypts and bottle trees.

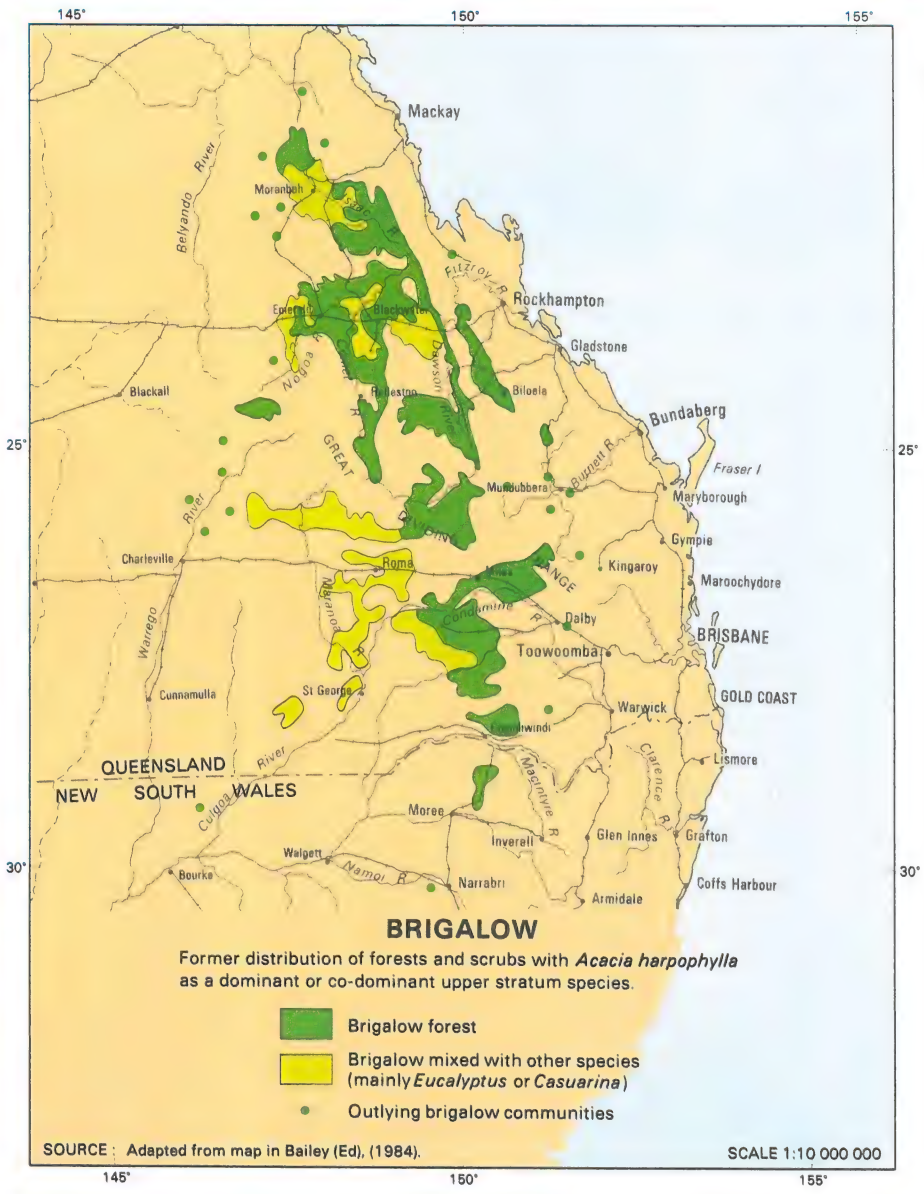
These forests remained largely unaltered well into the 20th century, apart from the dramatic infestation by prickly pear (*Opuntia*) and the equally dramatic biological control of this pest in the 1920s and 1930s. Although it was known that the fertile clay soils of the brigalow country were well suited to cropping or pasture, brigalow proved very difficult to clear because it grew densely and regenerated vigorously from suckers.

It was not until the 1950s, when the ringbarkers were replaced by bulldozers, that large scale clearance began in the southern section of the brigalow lands. Only after 1962, when the Commonwealth and Queensland governments introduced the Land Development (Fitzroy Basin) Scheme to encourage clearing, were the northern brigalow lands opened up. Under the 'Brigalow Scheme', as it was better known, more than 100 000 ha were cleared annually until the mid 1970s.

Early clearing aimed to increase the carrying capacity of the land by encouraging the growth of native grasses. However, it was the introduction of exotic pasture species which gave the greatest impetus to the development of the brigalow lands. The most successful of these was buffel grass (*Cenchrus ciliaris*) which is still the most widely sown pasture type in these areas.

Between 1961 and 1976 the area of sown pastures in Queensland's brigalow belt rose from 335 000 to 2 146 000 ha and cattle numbers increased by some half million. Since that time most of the brigalow clearance has been for cropping, for both fodder and cash crops such as oilseeds and cereals.

The development of the brigalow lands has been an agricultural success story—so successful in fact that most of the brigalow lands have now been cleared. The clearing of mixed brigalow scrubs is continuing and many of the surviving patches are regrowth from previous clearing attempts. With less than 1% of the original brigalow lands now in national parks and other reserves, the few remaining examples of natural forests may have a greater value in conservation than in agricultural production.



Brigalow forest
*The photo at right shows brigalow forest (**wM3L**) photographed in the 1960s prior to clearing, showing a dense understorey of low trees. In contrast, the only evidence of the natural vegetation in brigalow country cleared for cropping (far right), is the remaining bottle trees* (Brachychiton rupestris).

Plantations

Total area of plantation forests has risen from 3000 km^2 in 1967 to almost 10 000 km^2 today. *Pinus radiata* (pictured) forms the bulk of forest plantations across southern Australia. *P. elliottii* and *P. caribaea* and the native *Araucaria cunninghamii* are the main species grown in Qld. The total area of *Eucalyptus* hardwood plantations remains small; around 600 km^2, not including enrichment plantings of harvested natural forests. The main species planted are *E. regnans* in Vic., *E. nitens* and *E. delegatensis* in Tas. and several other species in NSW.

PLANTATION FORESTS

Only areas larger than 3000 hectares are mapped

- Pine plantations
- Native species plantations (*Araucaria, Callitris* and *Eucalyptus*)

SCALE 1:30 000 000

SOURCE: Adapted from data in Booth (1984).

Dieback

Dieback, or vegetation crown decline, was noticed as far back as 1880 and is a result of stress-induced ailing (Old and others 1981). The stresses which may destroy the plant crown include drought, insect attack, fungal disease, salinity, increased exposure, changes in soil nutrient status and root trampling.

No single factor, or combination of factors, seems to be consistently the cause of dieback, since plant susceptibility to stress varies in time and place. Plant species are affected differently through their geographical ranges. A species at the limit of its distribution already endures greater environmental stresses than in the middle of its range and may therefore be more susceptible to dieback.

The largest area of dieback in Australia occurs in the grazing country on the New England tablelands where the disease seems to be largely caused by insect attack, especially after frequent and severe attacks by scarab beetles, stick insects, psyllids or sawflies. This problem may have been increased by tree clearing and the establishment of pastures for grazing. In recent decades dieback has contributed to the change from woodland to open woodland in this area. The photo (left) shows severe dieback of woodland trees on farmland near Armidale.

In WA the dominant cause of dieback is contact with *Phytophthora cinnamomi*, a fungal disease which prefers poorly drained, infertile soils. The notable example of dieback in the jarrah (*Eucalyptus marginata*) forests (**eM3L**) in the south-west has created large areas of **eM2Z** in the present vegetation. The disease has affected not only the eucalypt forest but also the heathlands and *Banksia* woodlands in the south, endangering communities of rare shrubs. The fungus is naturally spread through the soil and, with increasing use of vehicles in the forests, it has been transported rapidly. The current attempts to control further spread are through effective hygiene measures such as washing down vehicles and restricting public access.

DIEBACK

Areas of reported tree dieback

SCALE 1:30 000 000

SOURCE: Adapted from map in Heatwole and Lowman (1986).

Woodland change

In terms of the area involved, the clearing of woodland has been one of the most significant historical vegetation changes. The wheatbelts in inland south-eastern and south-western Australia are to a large extent within areas formerly occupied by woodland. Much of this woodland has been transformed into an agricultural landscape of pastures and crops, where the only remnants of the former vegetation occur as isolated uncleared patches or narrow strips along road verges.

In total about 500 000 km^2 of natural woodland area (both **M2** and **L2**) are now occupied by other vegetation types, chiefly tussock grassland and sown pasture. This figure represents only about one-third of the total original woodlands, but within much of this area there has been an almost total elimination of the native elements of the vegetation. Most of the dominant species of the canopy survive as individual standing trees, but much of the initial diversity of the understorey and ground cover has been lost because of the dominant force of repeated cultivation, grazing and weeds.

Large parts of the cleared agricultural lands of eastern Australia formerly supported layered woodlands with dense low tree and shrub understoreys. The reduction in biomass and transpiration that results from the clearing of these woodlands (**M2L**) may be as significant as that resulting from forest clearing.

Throughout the cropping and intensive animal production areas, the replacement of the now senile population of standing trees is threatened by insufficient regeneration. This is largely the result of continuous grazing of seedlings by domestic stock, but the additional stresses which cause dieback in adult trees also affect juveniles. In some areas, such as the New England area of northern NSW, the partial removal of timber has been followed by many deaths through dieback among the remaining trees (Old and others 1981).

The low woodlands occur mostly in drier areas and remain largely unaltered, but in the grazing lands of the south-east they have been subject to clearing and thinning. Areas of *Acacia* and *Casuarina* low woodland through inland NSW and Qld have also been thinned or partially cleared in patches to increase livestock carrying capacity.

Open woodland is a widespread vegetation structure, in total (both **M1** and **L1**) covering nearly 2 million km^2. Low open woodland with either hummock or tussock grass understoreys occupies about 80% of this area.

The area of open woodland (**M1**) has doubled in the last 200 years, from about 175 000 km^2 to over 400 000 km^2. This results primarily from the creation of artificial open woodland by the partial clearing of forest and woodland. Selective clearing and ring-barking in these areas have left only the largest trees for shade and shelter. In places this coding describes the average cover of areas where there are remnant patches of denser vegetation within largely cleared lands. Areas such as these appear as 'tree thinning' on the Major Vegetation Changes map.

The area of low open woodland has also increased since European settlement, partly through the invasion of the Afro-Asian prickly acacia (*Acacia nilotica*) over about 50 000 km^2 of former grassland in north-central Qld. It is the most significant historical increase in upper stratum vegetation. The remainder of the increase is the result of thinning in low woodlands.

Remnants of former bushland along a roadway in the SA wheatbelt
The importance of these uncleared islands and corridoors as repositories of the former diversity of the vegetation has now been recognised and in several states many roadside verges are now protected.

Prickly acacia

Acacia nilotica was introduced to the treeless Mitchell grass plains for shelter and fodder and in the last decade has undergone a huge increase from initial infestations around the major towns in the region. It has invaded about 50 000 km^2 of former grassland in north-central Qld, which appears as the green area on the map of major vegetation changes. The spread of prickly acacia is associated with watercourses and stock movements and it now forms a low open woodland with localised areas of low woodland. In the early stages of infestation the younger plants tend to be tall shrubs rather than low trees, as shown in the photo below taken on Olive Downs station near Richmond. There are large concentrations around the towns of Richmond, Hughenden, Muttaburra and Winton and it is spreading into the Longreach area. This Afro-Asian species is ideally suited to an ecological niche unoccupied by any of the native trees or shrubs.

Shrubland change

Within the tall shrublands, large areas of the distinctive mallee and mulga vegetation have been altered by European land use; the mulga primarily by sheep grazing and the mallee by cultivation for crops and pasture. The reduced cover in the mulga and the replacement of mallee by sown pasture, together account for most of the change in the area of tall shrubland.

The total area of tall shrubland has fallen by about 35% over the last 200 years. In terms of the area involved this rivals the reduction of woodlands, but the greater part of this change has been a general decline in shrub density in the *Acacia* shrublands associated with pastoral land use.

Much former *Acacia* shrubland is now coded as tall open shrubland. In some areas *A. aneura, A. papyrocarpa, A. loderi* and *A. pendula* have become degraded and, apart from the diminution of tall shrubs, understoreys of low shrubs and grasses have also been modified.

In parts of the WA mulga the palatable species of the former low shrub layer have been eliminated through grazing. In contrast, in western NSW, the historical increase in the low shrub layer is also a result of pastoralism. Overgrazing in parts of the mulga has led to a secondary succession dominated by annual grasses such as *Aristida* and *Enneapogon*, leaving the ground largely bare during dry times. These are examples of more widespread shifts in structure and floristic composition that have occurred in response to the new selection pressures imposed by alien herbivores.

Roughly 160 000 km^2 of tall shrubland have been cleared for cropping and pasture and this has been concentrated in former mallee lands. In the east the clearing of mallee was well underway by the 1920s but it is a more recent development in the west. The area sown to wheat in WA almost trebled between 1961 and 1981, from 16 000 km^2 to 46 000 km^2. Most of this was cleared from tall shrub formations; mallee, mallee-heath, scrubs of *Acacia* and *Casuarina*, and mixed scrub-heaths. The clearing of mallee vegetation in several states has continued to push into areas both climatically and edaphically marginal for dryland wheat production.

Most of the area dominated by low shrubs is covered by species of saltbush (*Atriplex*), bluebush (*Maireana*) and other related genera of the family Chenopodiaceae. These have undergone an overall decline in shrub density and foliage cover across most of their original range. They are now mapped as low open shrubland, but to some extent this coding masks inherent shrub density variations not visible on satellite imagery.

The biggest impact has been the advent and continued presence of sheep. Chenopod shrubs are both palatable and easily accessible to sheep and, during dry times, may constitute almost their entire diet. Nevertheless, these shrubs have survived sometimes intense grazing pressure over most of their range. Rabbits have also contributed to the decline of low shrubland. On the Nullarbor Plain, where there has been only limited sheep grazing, shrub thinning is attributed to the combined effects of rabbits, fire and drought.

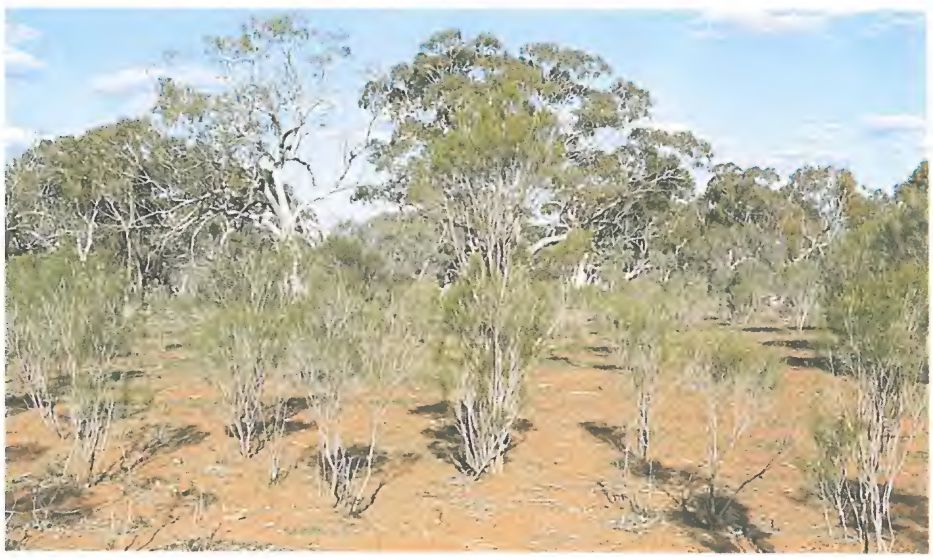
Alpine vegetation has also been modified by grazing and burning. The former pattern of summer grazing and autumn burning resulted in a decline of sensitive species and accelerated soil erosion. In the Mt Kosciusko region grazing was phased out by the 1960s but some areas have yet to recover completely.

Grazing and feral animals

About two-thirds of Australia is subject to grazing by domestic stock. Most of the unused area has a hummock grass ground cover, is poorly watered, or is rugged and remote. A variety of feral animals has increased the often intense pressures on natural vegetation within pastoral areas and brought new patterns of plant predation to the undeveloped lands.

The rabbit has been the most destructive of the pest animals in terms of its historical effect on the vegetation. It has been implicated in the decline of several shrubland types and in the poor regeneration of a number of native plant species, through increasing the grazing pressure on herbaceous plants and, during dry times, damaging shrubs and tree seedlings.

In the first half of this century huge rabbit populations (below) developed in southern Australia. After successful biological control in the 1950s rabbit numbers declined sharply, but in recent years have increased again to some 200 million. The area where rabbit populations are well established is shown on this map, along with present grazing lands. They are frequently found further north, in isolated colonies on lighter soils.



Shrub regrowth

The increased incidence of woody shrubs is common in disturbed natural vegetation in many parts of the world. In the semi-arid grazing lands of north-western NSW and south-western Qld the unrestricted growth of inedible native shrubs has given rise to dense stands which suppress native pasture growth and severely reduce stock carrying capacity. The major infestataions have occurred on the sandplain country to west and north of Cobar and Bourke, but over half of western NSW is affected by woody shrub regrowth.

The major species involved come from the common inland genera *Cassia, Eremophila* and *Dodonaea* and most were only occasional components of the vegetation when settlers first moved into these areas. Massive germination of these shrubs has occurred in favourable seasons and they have proved so difficult to control that they have been labelled 'woody weeds'. Dense regeneration of otherwise desirable plants such as mulga or cypress has also been incuded in this category.

The original vegetation of the worst affected areas was low open woodland or tall open shrubland with a ground cover of perennial tussock grasses. A combination of environmental factors has led to the increase of shrubs and the present ground cover of annual grasses, but the exact mechanism of this shift is unclear because of the fundamental changes in the ecosystems of western NSW. Large scale devegetation and soil loss occurred as a result of drought and overgrazing over the last 100 years.

A decline in ground cover under grazing and the suppression of fires by landholders have reduced fire frequency. Ground cover is often too low in shrub infested areas to carry fire at all. More frequent burning in the past probably prevented shrub establishment. The main woody weed species, however, appear to be well adapted to fire. Many, notably budda (*Eremophila mitchellii* pictured near Cobar) are able to resprout after fire. Several, including hopbush (*Dodonaea viscosa*), and punty bush (*Cassia eremophila*) display fire promoted germination and early reproductive maturity. Increasing the frequency of low intensity burns is seen as the best option for future control of the woody weeds.

The new vegetation

Perhaps the most significant vegetation change that has come with the establishment of present land use is the creation of an agricultural landscape of tussock grassland, sown pasture and crops. This has replaced vegetation of entirely different growth forms, and has introduced new species and a new structural form of vegetation—the swards of the exotic sown pastures.

The pastures are either perennial, such as those of the wetter coastal valleys, or annual, where they may alternate with a variety of crops. They are composed of introduced legumes and grasses, and are grazed to a low sward. Cropping is based on the cyclic domination of single species stands. The best example of this is the annual wheat crop, which for part of the year covers about 120 000 km^2.

Sown pastures now dominate over 400 000 km^2 or more than 5% of the continent. They also form the understorey to a further 50 000 km^2 of open woodland in the south-east. Once established, most of the pasture grasses are self-generating, while many of the native species decline under livestock grazing. Without the addition of fertilisers, however, their grazing value is similar to that of the native species.

The addition of legumes to pastures increases soil nitrogen as well as the amount of protein available to domestic stock, but they also require fertilisers to become well established. The rise to dominance of the legume pastures across southern Australia, most notably that of subterranean clover (*Trifolium subterraneum*), came with the widespread application of superphosphate during and after the 1920s. Since then the identification of trace element deficiencies in many regional soils has improved pasture establishment.

In tropical Australia the search for suitable legumes to accompany the numerous introduced grasses and to increase the grazing value of northern pastures has seen the introduction of a variety of species. These are mostly from tropical Africa and America and include several species of *Stylosanthes*, such as Townsville stylo (*S. humilis*) and the widely sown Siratro (*Macroptilium atropurpureum*). But there are still few persistent legumes suited to the heavier clay soils of the brigalow country, so pasture sowings in these areas are usually of pure grasses, such as buffel grass (*Cenchrus ciliaris*), Rhodes grass (*Chloris gayana*) and Guinea grass (*Panicum maximum*).

The area occupied by tussock grasslands has increased by about half and now covers around 9% of Australia. As well as this expansion in area, present land use has led to changes in density and floristic composition within the grasslands. These grasses are also the understorey in a wide range of vegetation types, as depicted on the Grass Cover map opposite.

Salinity

Land salinisation is a consequence of the widespread removal of natural vegetation, unforseen when the major clearing for agriculture began. The process which has led to the salinisation of productive farmland in the WA wheatbelt (pictured) and the lower Murray River basin is primarily the result of reduced transpiration, increased groundwater recharge and rising water-tables.

There are vast areas of naturally saline soils throughout Australia and most of these overlie saline, and often quite shallow, groundwater bodies. In many such areas there is a salt-adapted flora, most notably saltbush, bluebush and samphires.

Dense deep-rooted vegetation acts as a natural pump by cycling much of the water which enters the soil back into the atmosphere through transpiration. With the removal of this vegetation the natural balance between infiltration and transpiration is broken and the amount of water which enters the groundwater increases. The level of the water-table gradually rises as a result and eventually reaches the surface in low-lying areas, killing the vegetation. Salt is further concentrated in these seepages by evaporation.

Major clearing began in the WA wheatbelt and the lower Murray basin during the 1920s and the problems of land salinisation only became apparent in the 1970s. In WA about 3500 km^2 have been affected and this area is increasing. Along the lower Murray the problem is increased by the addition of large amounts of irrigation water to the shallow saline groundwater.

Weeds

Some plant species have proved very difficult to control and become serious weeds when they impinge upon economic activities or the integrity of natural areas. Plants are given weed status for a variety of reasons, such as toxicity to stock, competition with desirable species or spoilage of agricultural products.

The weeds in Australia are both native and exotic species. Native plants have become pests in agricultural areas where they compete with plants of agricultural value. The bracken fern (*Pteridium esculentum*) and the woody weed shrubs are native species which compete with forage grasses.

Of the thousands of introduced species, many that have become well established are now classed as weeds and are permanent additions to the flora. They are generally confined to disturbed lands but there are exceptions such as the blackberry (*Rubus fruticosus*), which is a major weed in areas receiving more than 750 mm of rainfall across southern Australia.

Blackberry is not only a pest of grazing lands but has also displaced native shrub species along stream banks in largely natural bush. Others have found unoccupied ecological niches, such as *Acacia nilotica* on treeless clay plains where no native *Acacia* species occur, or the numerous weeds of grassland which have increased with the grazing of native grasses.

Certain agricultural weeds are found only on soils with high nutrients and appear only after pasture improvement. Cape weed (*Arctotheca calendula*) and a number of the thistles fall into this category. Others occur largely on poor soils. Many weed plants originated from Europe, the Mediterranean region or South Africa.

A well-known example is Paterson's curse (*Echium plantagineum*), a Mediterranean garden plant introduced to SA in the 1850s. It spread rapidly, was recognised as a problem in NSW by the 1880s and is now widespread in the eastern States.

Paterson's curse is also known as Salvation Jane in the drier parts of SA (pictured) where it provides some valuable feed, yet in quantity it may be poisonous to stock. It is also considered a valuable honey plant and this has led to recent controversy over the release of a potential biological control organism. Honey producers saw this as a threat to a valuable source of early-season pollen and nectar.

There has been a decline in the foliage cover of the tropical Mitchell grass vegetation over much of its range as a result of continuous grazing by both cattle and sheep. There has also been a general decline in native grass cover throughout the semi-arid woodlands and shrublands, although this is not often apparent on the maps. Long-term cover changes may be difficult to detect in inland areas where the foliage cover of grasses is subject to enormous fluctuations.

Shifts in species composition have also been widespread. The introduction, both accidental and deliberate, of a large number of exotic grasses has created obvious floristic changes but within the native grasslands there have also been shifts in the relative dominance of different species under grazing.

Most of the grasses which now occur in temperate woodland areas of the south-east are part of grazing-induced disclimax communities of short, cool-season grasses such as *Stipa falcata* and *Danthonia* species. These areas were formerly dominated by taller perennials which grew during the warm season, in particular *Themeda australis* and *Stipa aristiglumis* (Moore 1970). Grazing disturbed the balance which maintained these species in favour of winter growing and annual types. In pasture-improved areas there has been an increase in exotic annuals such as *Vulpia* and *Bromus*. *Themeda* has withstood grazing in summer rainfall areas and remains an important component of the northern grasslands.

Introduced grasses have replaced native species particularly under intensive management. Most native grasses are slow-growing and are adapted to low nutrient soils, so they tend to be disadvantaged by the intensive grazing and added fertilisers of modern agricultural practice. In the south-west of WA the native grasses were rapidly displaced by grazing and the industry is now entirely based on sown pasture species.

In addition to the 146 genera of grasses that are native to Australia, there are now also 64 naturalised exotic genera. Most of these new genera have a temperate origin, and are represented in the pastures and crops by such genera as *Lolium, Phalaris, Vulpia, Hordeum* and *Triticum*. Some widespread introduced grasses of tropical origin, such as *Cenchrus, Brachiaria, Panicum, Paspalum* and *Pennisetum*, are from genera which also have native Australian species (Clifford and Simon 1981).

The process of the rise and decline of species is as old as the continent itself, but the vegetation has been rapidly and fundamentally changed by the introduction of thousands of new plant species over the last 200 years. Many of these, such as crop and pasture plants, are restricted to cultural landscapes, but even in largely unmodified areas the flora has been permanently changed by the invasion of naturalised exotic species.

Grass cover

In the last 200 years the total area of tussock grassland has risen from 500 000 km^2 to over 700 000 km^2. This overall increase actually masks some apparent losses of grassland, most notably to *Acacia nilotica* woodland over 50 000 km^2 of Mitchell grass country in Qld.

A better indication of the total increase in the coverage of grasses is given by including all vegetation types with a grassy understorey, as most such areas are grazed and many woodlands, shrublands and even forests have been modified to increase their grazing potential. The total area of vegetation with a ground cover of tussock or sward grasses, which includes the sown pastures, has risen from about 38% to its present coverage of 50% of the continent.

Even this is an underestimate of the extent of grasses, because the map coding system identifies at most two layers of vegetation. As a consequence, where other understorey types occur over grass, it is not shown.

This map shows the extent of tussock grasslands, sown pastures and other vegetation with a grassy understorey. The green areas are the original grassy vegetation types and the blue areas are increases, mainly in agricultural areas, but also in pastoral country where the thinning of woody natural vegetation has increeased the prominence of grasses.

The areas in western NSW where a grassy understorey has been reduced by dense shrub growth stand out as the major loss of grasses, although other examples where grass cover has declined do not appear.

The next 200 years?

The period 1990 to 2000 has been designated the Decade of Land Care in Australia. There is worldwide concern that time is running out for natural ecosystems exploited by humans. Australia has the advantages of a small population and large natural areas, but the retention of part of the woody vegetation cover is no less important if agricultural production is to be maintained and further environmental crises of our own making are to be avoided.

The role of the loss of tree and shrub cover in contributing to the growing environmental problems facing this country has now been recognised. Retaining trees actually enhances the long-term productivity of agricultural land by protecting soils, providing shelter and reducing salting.

It is now Australian Government policy to attempt to replace some of the billions of trees which have been removed, mostly from agricultural areas. Among the initiatives on the environment is the establishment of baseline data on the distribution and condition of natural resources. This is seen as essential for monitoring the predicted greenhouse effect changes and as a first step to balanced decision making, but the real work of rehabilitation and conservation must take place on the ground.

We have reached a critical stage in the development of this country's vegetation resources. There has been a gradual change in people's attitudes to the use of the land, yet in the last decade thousands of square kilometres of natural vegetation were cleared on the margins of agricultural areas. This trend may be reversed in many areas in the coming decade as efforts are put into regeneration and replanting. The strength of present community concern is seen in farmers and conservation groups joining forces to plan the rehabilitation of degraded farmland.

The management of native forest resources has also reached a turning point, as the reconciliation of the dual roles of timber production and conservation comes under close investigation. There are proposals for an expansion of eucalypt plantation forests to rival the area of pine plantations, which would see a return to forest vegetation in parts of its former range.

Index of common names

The internationally accepted Latin nomenclature is generally used for plant names in this volume. Only restricted use is made of common names because they are often a source of confusion. Many species are known by different common names in different parts of the country, and conversely the same common name may be applied to several different species. Further, some of the common names of Australian plants are also those of quite different European plants. However, recommended common names for the plants referred to by Latin names in the text are listed in the Index of common names on this page. Crop plants are not listed because their common names are given in the text.

Most of the botanical and common names given in this volume are those used by Hartley (1979). There are a few variations. For example, Johnson (1982) has transferred many of the species of *Casuarina* to the new genus *Allocasuarina*; however, general references to *Casuarina* cover both genera. In the case of *Callitris*, the treatment of Thompson and Johnson (1986) is followed. Some authors consider that *C. columellaris*, *C. glaucophylla* and *C. intratropica* should all be assigned to *C. columellaris*. However, it is ecologically convenient to recognise separate eastern coastal, inland, and northern tropical elements.

Pedley (1986, 1987) has proposed that most of the Australian species of *Acacia* should be transferred to *Racosperma*; however, the traditional names are used in this volume. Pryor and Johnson (1971) distinguished several subgenera within *Eucalyptus*, and it has been proposed to raise these to generic rank (Morley and Toelken 1983). Species of *Eucalyptus* that would be transferred to other genera are indicated in this index by appending the letter B (*Blakella*), C (*Corymbia*), E (*Eudesmia*) or S (*Symphyomyrtus*).

The first volumes of a new fifty-volume *Flora of Australia* are now appearing (Bureau of Flora and Fauna, 1981–). There is a wide range of published guides to the plants of particular regions or botanical groups, many of which are illustrated and give both botanical and common names. Advice about these publications is available at State or Territorial herbaria and botanical gardens.

Botanical name	Common name
Acacia acuminata	Raspberry jam
A. aneura	Mulga
A. argyrodendron	Black gidgee, Blackwood (Qld)
A. brachystachya	Umbrella mulga
A. cambagei	Gidgee
A. catenulata	Bendee
A. coolgardiensis	—
A. coriacea	Desert oak
A. dictyophleba	—
A. eriopoda	Broome pindan wattle
A. georginae	Georgina gidgee
A. harpophylla	Brigalow
A. kempeana	Witchetty bush
A. ligulata	Sandhill wattle
A. linophylla	Bowgada
A. loderi	Nelia
A. lysiphloia	Turpentine wattle
A. melanoxylon	Blackwood
A. neurophylla	—
*A. nilotica**	Prickly acacia
A. pachycarpa	—
A. papyrocarpa	Western myall
A. pendula	Weeping myall, Boree
A. petraea	—
A. pycnantha	Golden wattle
A. pyrifolia	Kanji
A. quadrimarginea	—
A. ramulosa	Horse mulga
A. resinomarginea	—
A. shirleyi	Lancewood
A. stenophylla	Belalie
A. stipuligera	—
A. stowardii	Bastard mulga
A. tephrina	Boree (Qld)
A. tetragonophylla	Dead finish
A. tumida	Pindan wattle
A. victoriae	Prickly wattle
A. xiphophylla	Snakewood
Acanthocarpus preissii	—
Adansonia gregorii	Boab, Baobab
*Aerva javanica**	Kapok bush
Albizia basaltica	Red lancewood
Allocasuarina acutivalvis	—
A. campestris	—
A. corniculata	—
A. decaisneana	Desert sheoak
A. luehmannii	Bull oak
A. pusilla	Dwarf sheoak
A. verticillata	Drooping sheoak
Alphitonia spp.	Red ash
Araucaria bidwillii	Bunya pine
A. cunninghamii	Hoop pine
*Arctotheca calendula**	Capeweed
Aristida spp.	Threeawn
Astrebla elymoides	Hoop Mitchell grass
A. lappacea	Curly Mitchell grass
A. pectinata	Barley Mitchell grass
A. squarrosa	Bull Mitchell grass
Atalaya hemiglauca	Whitewood
Atriplex nummularia	Old man saltbush
A. spongiosa	Pop saltbush
A. vesicaria	Bladder saltbush
Avena spp.*	Wild oats
Avicennia marina	Grey mangrove
Azorella selago	—
Banksia attenuata	Coast banksia
B. marginata	Silver banksia
B. ornata	Desert banksia
B. serrata	Sawtooth banksia
Bedfordia spp.	Blanket leaf
Bothriochloa spp.	Bluegrass
B. macra	Redleg grass
*B. pertusa**	Indian bluegrass
Brachiaria spp.*	—
Brachychiton australis	Broadleaf bottle tree
B. rupestris	Queensland bottle tree
Bromus spp.*	Brome
Buchanania spp.	Buchanania
Callicoma serratifolia	Callicoma
Callitris columellaris	Coast cypress pine
C. endlicheri	Black cypress pine
C. glaucophylla	White cypress pine
C. intratropica	Northern cypress pine
C. preissii	Rottnest Island pine
Carex spp.	Sedge
Carissa spp.	Carissa
*Carrichtera annua**	Ward's weed
Cassia spp.	Cassia
C. eremophila	Punty bush
Casuarina cristata	Belah
*Cenchrus ciliaris**	Buffel grass
*C. setiger**	Birdwood grass
*Centrosema pubescens**	Centro
Chenopodium auricomum	Queensland bluebush
Chloris spp.	Chloris
*C. gayana**	Rhodes grass
Chrysopogon spp.	Ribbon grass, Beard grass
Cycas spp.	Cycas
Cyperus spp.	Flat sedge
*Dactylis glomerata**	Cocksfoot
Danthonia spp.	Wallaby grass
Desmodium spp.*	Desmodium
Dichanthium spp.	Bluegrass
D. sericeum	Queensland bluegrass
*Digitaria decumbens**	Pangola grass
Dodonaea spp.	Hopbush
D. viscosa	Sticky hopbush
Doryphora aromatica	Grey sassafras

Botanical name	Common name
Echinochloa turnerana	Channel millet
*Echium plantagineum**	Paterson's curse
Eleocharis spp.	Spike rush
E. dulcis	Water chestnut
Enneapogon spp.	Nineawn
Eragrostis spp.	Lovegrass
E. australasica	Swamp canegrass
Eremophila spp.	Emu bush
E. mitchellii	Budda, False sandalwood
Eriachne spp.	Wanderrie grass
Erythlophleum chlorostachys	Cooktown ironwood
Eucalyptus acmenoides	White mahogany
E. alba (S)	White gum
E. albens (S)	White box
E. argillacea (S)	Northern grey box
E. baxteri	Brown stringybark
E. behriana (S)	Bull mallee
E. bleeseri (C)	Smooth-stemmed bloodwood
E. botryoides (S)	Southern mahogany
E. brevifolia (S)	Snappy gum
E. calophylla (C)	Marri
E. camaldulensis (S)	River red gum
E. cambageana (S)	Dawson gum
E. coccifera	Tasmanian snow gum
E. crebra (S)	Narrowleaf ironbark
E. cullenii (S)	Cullen's ironbark
E. delegatensis	Alpine ash
E. dichromophloia (C)†	Variable-barked bloodwood
E. diversicolor (S)	Karri
E. diversifolia	Soap mallee
E. drepanophylla (S)	Queensland grey ironbark
E. dumosa (S)	White mallee
E. eremophila (S)	Mallee
E. fasciculosa (S)	Pink gum
E. ferruginea (C)	Rusty bloodwood
E. foecunda (S)	Narrowleaf red mallee
E. gamophylla (E)	Blue mallee
E. gomphocephala (S)	Tuart
E. gongylocarpa (E)	Desert gum
E. gracilis (S)	Yorrell
E. grandifolia (B)	Largeleaf cabbage gum
E. grandis (S)	Flooded gum
E. gummifera (C)	Red bloodwood
E. incrassata (S)	Ridge-fruited mallee
E. intermedia (C)	Pink bloodwood
E. intertexta (S)	Gum-barked coolibah
E. kingsmillii (S)	Kingsmill's mallee
E. largiflorens (S)	Black box
E. latifolia (C)	Roundleaf bloodwood
E. leucophloia (S)	Migum
E. leucoxylon (S)	Yellow gum
E. loxophleba (S)	York gum
E. macrorhyncha	Red stringybark
E. maculata (C)	Spotted gum
E. marginata	Jarrah
E. melanophloia (S)	Silverleaf ironbark
E. melliodora (S)	Yellow box
E. microcarpa (S)	Grey box
E. microtheca (S)	Coolibah
E. miniata (E)	Darwin woollybutt
E. nesophila (C)	Melville Island bloodwood
E. nitens (S)	Shining gum
E. obliqua	Messmate stringybark
E. ochrophloia (S)	Yapunyah
E. odorata (S)	Peppermint box
E. oleosa (S)	Giant mallee
E. ovata (S)	Swamp gum
E. pachyphylla (S)	Red-bud mallee
E. papuana (B)	Ghost gum
E. pauciflora	Snow gum
E. phoenicea (E)	Scarlet gum
E. pilularis	Blackbutt
E. polycarpa (C)	Longfruit bloodwood
E. populnea (S)	Poplar box
E. propinqua (S)	Smallfruit grey gum
E. pruinosa (S)	Silverleaf box
E. radiata	Narrowleaf peppermint
E. regnans	Mountain ash
E. saligna (S)	Sydney blue gum
E. salmonophloia (S)	Salmon gum
E. setosa (C)	Roughleaf bloodwood
E. sideroxylon (S)	Red ironbark
E. sieberi	Silvertop ash
E. signata	Scribbly gum
E. similis (E)	Inland yellow jacket
E. socialis (S)	Red mallee
E. tectifica (S)	Darwin box
E. tereticornis (S)	Forest red gum
E. terminalis (C)	Pale bloodwood
E. tetragona (E)	Tallerack
E. tetrodonta (E)	Darwin stringybark
E. transcontinentalis (S)	Redwood
E. viminalis (S)	Manna gum, Ribbon gum
E. viridis (S)	Green mallee
E. wandoo (S)	Wandoo
E. whitei (S)	White's ironbark
E. youngiana (S)	Ooldea mallee
Eulalia fulva	Silky browntop
Flindersia maculosa	Leopard wood
Frankenia spp.	Frankenia
Gahnia spp.	Saw-sedge
Geijera parviflora	Wilga
Grevillea spp.	Grevillea
Gymnoschoenus sphaerocephalus	Button grass
Hakea leucoptera	Needlewood
H. lorea (H. suberea)	Corkwood
Halosarcia spp.	Samphire
Helipterum spp.	Sunray
Heterodendrum oleifolium	Rosewood
Heteropogon contortus	Black speargrass
Hordeum spp.*	Barley grass
*Hyptis suaveolens**	Hyptis

Botanical name	Common name
Imperata cylindrica	Blady grass
*Lagurus ovatus**	Harestail grass
Leptospermum spp.	Teatree
Livistona spp.	Cabbage palm
*Lolium perenne**	Perennial ryegrass
*L. rigidum**	Annual ryegrass
Lomandra spp.	Matrush
Lysiphyllum carronii	Bauhinia
Macropteranthes kekwickii	Bulwaddy
*Macroptilium atropurpureum**	Siratro
Maireana aphylla	Cottonbush
M. astrotricha	Low bluebush
M. pyramidata	Black bluebush
M. sedifolia	Pearl bluebush
Medicago spp.*	Medic
*M. sativa**	Lucerne
Melaleuca spp.	Paperbark, Broombush
M. lanceolata	Moonah, Dryland teatree
M. leucadendra	Longleaf paperbark
M. quinquenervia	Five-veined paperbark
M. viridiflora	Broadleaf paperbark
*Mimosa pigra**	Giant sensitive plant
Muehlenbeckia cunninghamii	Lignum
Myoporum platycarpum	Sugarwood
Myriocephalus spp.	Poached egg daisy
*Neonotonia wightii**	Glycine
Nitraria billardieri	Nitre bush
Nothofagus cunninghamii	Myrtle beech
N. gunnii	Tanglefoot
N. moorei	Negrohead beech
Nypa fruticans	Mangrove palm
Olearia spp.	Daisy bush
Opuntia spp.*	Prickly pear
Oryza rufipogon	Wild rice
O. australiensis	Australian rice
Owenia reticulata	Desert walnut
Pandanus spp.	Pandanus
Panicum spp.	Panic
*P. maximum**	Guinea grass
P. whitei	Pepper grass
*Paspalum dilatatum**	Paspalum
*Pennisetum clandestinum**	Kikuyu grass
Petalostigma spp.	Quinine tree, Quinine bush
*Phalaris aquatica**	Phalaris
*Pinus caribaea**	Caribbean pine
*P. elliottii**	Slash pine
*P. pinaster**	Maritime pine
*P. radiata**	Monterey pine
Planchonia careya	Cocky apple
Plechtrachne pungens	Curly spinifex
P. schinzii	Feathertop spinifex
Poa spp.	Poa
Podocarpus lawrencei	Mountain plum pine
Podolepis spp.	Podolepis
Pomaderris spp	Pomaderris
Pringlea antiscorbutica	Kerguelen cabbage
Pteridium esculentum	Bracken
Ptilotus spp.	Mulla mulla
Rhizophora stylosa	Red mangrove
*Rubus fructicosus**†	Blackberry
Sarcocornia spp.	Glasswort
Sclerolaena divaricata	Tangled copperburr
S. eriacantha	Silky copperburr
S. lanicuspis	Woolly copperburr
Sclerostegia spp.	Samphire
Sehima nervosum	Whitegrass
Sida spp.	Sida
Sorghum spp.	Native sorghum
Spinifex hirsutus	Beach spinifex
Sporobolus spp.	Rat's tail grass
S. virginicus	Saltwater couch
Stipa spp.	Corkscrew grass
S. aristiglumis	Plains grass
S. falcata	Slender speargrass
S. variabilis	Variable speargrass
*Stylosanthes humilis**	Townsville stylo
Syncarpia glomulifera	Turpentine
Terminalia spp.	Terminalia
Themeda australis	Kangaroo grass
Thyridolepis mitchelliana	Mulga grass
Trifolium spp.*	Clover
*T. repens**	White clover
*T. subterraneum**	Subterranean clover
Trigonella suavissima	Cooper clover
Triodia basedowii	Lobed/Hard spinifex
T. clelandii	Weeping spinifex
T. irritans	Porcupine grass
T. microstachya	—
T. mitchellii	Eastern spinifex
T. pungens	Soft spinifex
T. scariosa	Buck spinifex
T. wiseana	Limestone spinifex
Ventilago viminalis	Supplejack
Vulpia spp.*	Rat's tail fescue
Xanthorrhoea spp.	Grasstree
Xerochloa spp.	Rice grass
Xylocarpus spp.	Cedar mangrove
*Ziziphus mauritiana**	Chinee apple
Zygochloa paradoxa	Sandhill canegrass

* introduced species
† taxonomic complex

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Brian Lees: page 40 *(top left)*.

Ian Morris: page 8.

Geoff Parkinson: page 31 *(bottom)*.

Rosemary Purdie: page 46.

Queensland Forest Service: pages 18 *(right)* and 23 *(centre)*.

Reader's Digest: Robin Morrison page 21 *(left)*.

Alyx Russell: page 49 *(top)*.

Mark Schuster: pages 18 *(left)* and 21 *(right)*.

Edward Stokes: pages 16 *(upper centre)*, 17 *(lower centre)*, 37 and 50 *(bottom)*.

Richard Turner: page 57 *(bottom)*.

Weldon Trannies: Ray Joyce page 25 *(centre)*; **George Hall** page 51 *(top right)*; **Leo Meier** cover and page 39 *(upper centre)*.

Wildlight: Jonathan Chester page 41 *(bottom)*; **Mark Lang** pages 4–5.

Cliff Winfield: page 44 *(bottom)*.

Other acknowledgements

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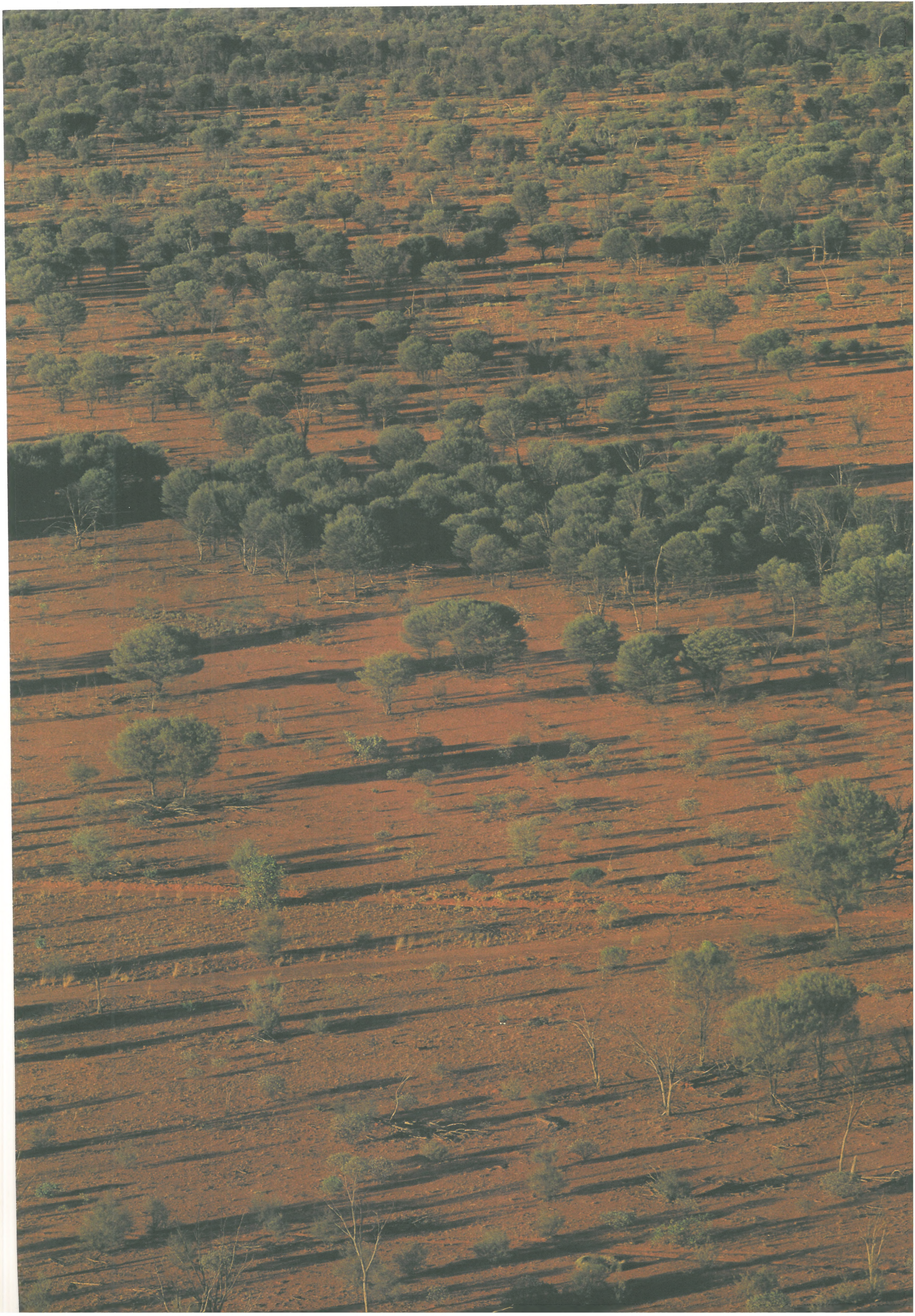
The Australian Centre for Remote Sensing provided the six Landsat scenes used on pages 12 and 13.

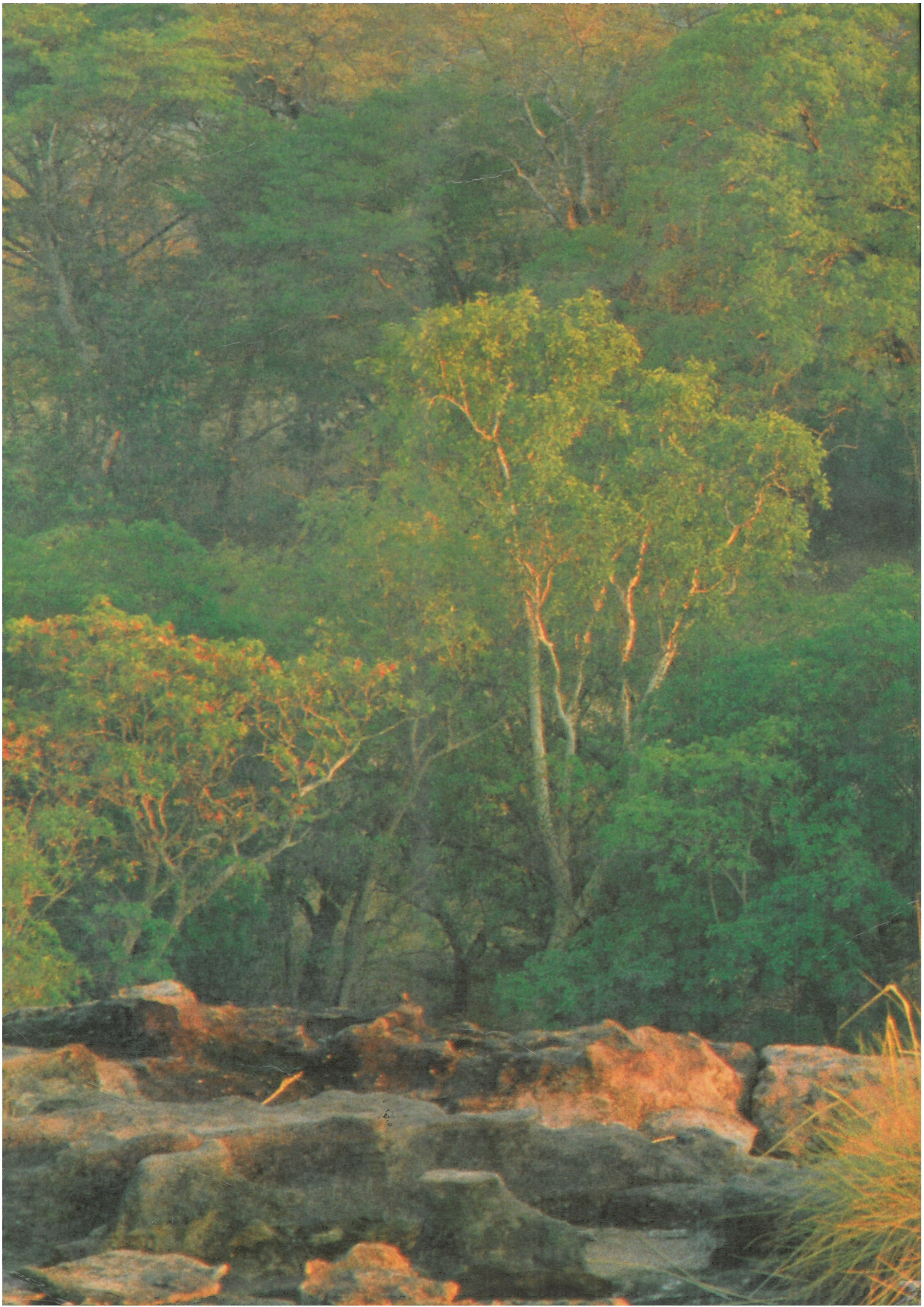
The data for the digitally derived small maps in this volume were generated using ERDAS (Earth Resources Data Analysis System) GIS software (version 7.3) housed on an IBM AT personal computer. They are based on the overlay of scanned digital copies of the 1:5 million scale maps from a SCITEX R280 scanner–plotter.

The map of the world distribution of moist tropical forests on page 21 is reproduced courtesy of *The Economist* newspaper.

The map of Australia's tropical World Heritage rainforest on page 21 is a Landsat image classification which was developed as part of a collaborative research project by the Centre for Resource and Environmental Studies (CRES), Australian National University and the Cartographic Unit (AUSLIG).

The original illustrations for the pictorial key on page 11 were drawn by Ted Deveson.





ERRATA

page 22 paragraph 2:

Roughly half of the existing open forests (140 000 km^2) lie within.....

page 41 paragraph 2:

(k22G) should read **(kZ2G)**

page 54 table 2:

Natural area of Hummock grasses should read 2070 or 26.9%

page 55: caption to diagram - last sentence

The gain of 400 000 km^2 comes from former forest (100 000), woodland (260 000) and....